The Assimilation of Surface Sensitive Microwave Observations Over Land: Recent Results and Open Issues

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and many colleagues from Météo-France

CNRS INSU Observer & comprendre

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Outline

On the need for a good knowledge of emissivity

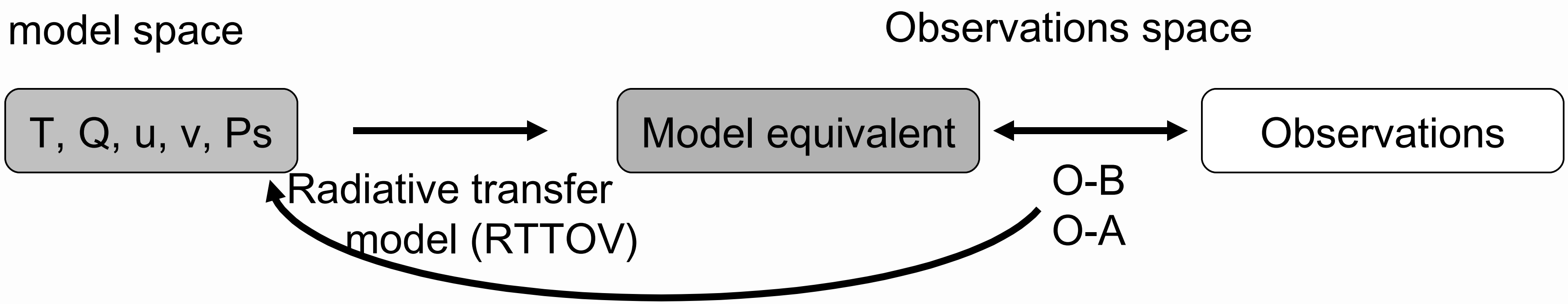
Variability factors of emissivity

Use of AMSU-A & AMSU-B/MHS data over land and preparations for SSMIS

The sea-ice issue

On the need for a good knowledge of emissivity

Satellites observations: Tbs

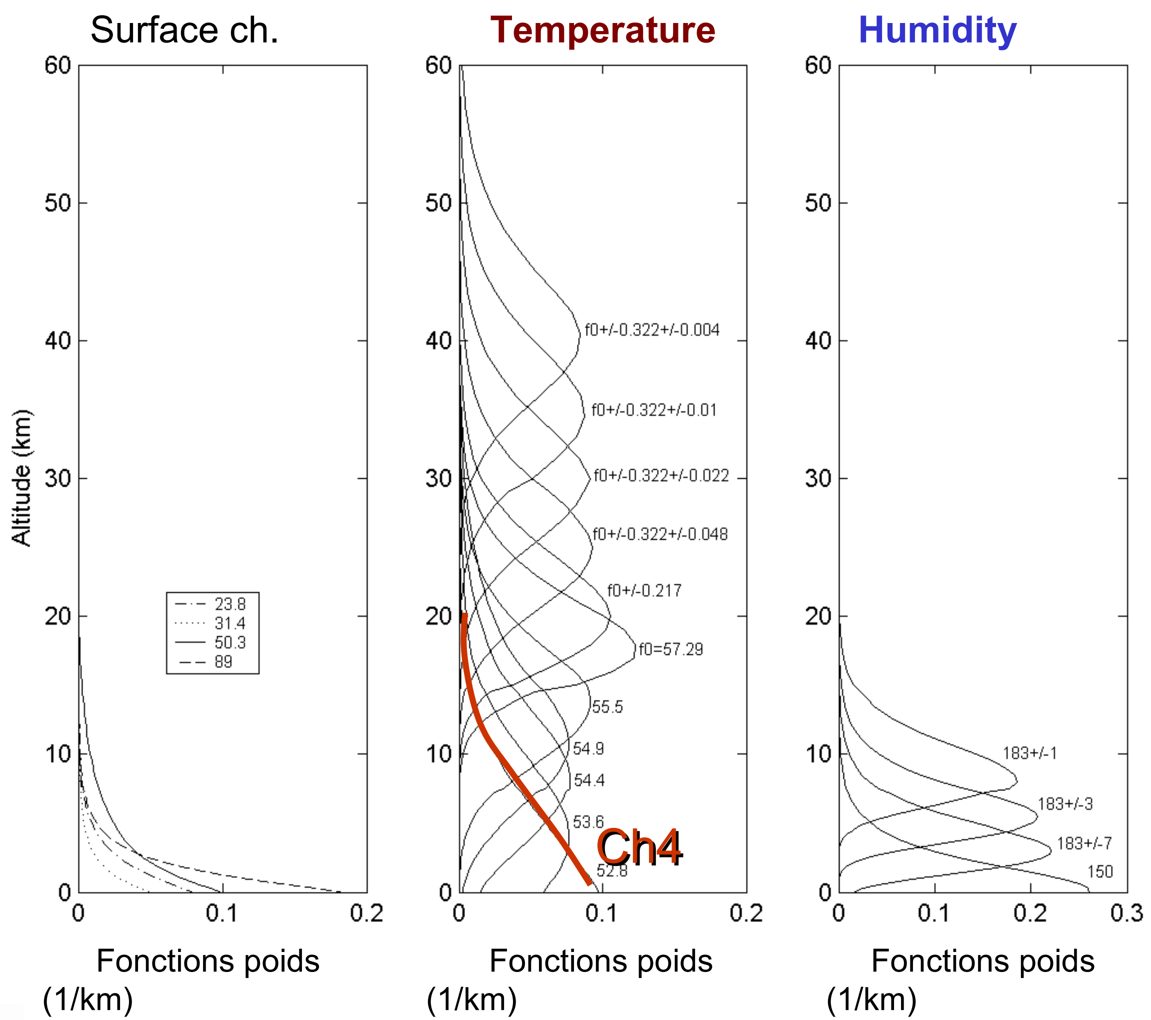


- **Simulations of radiative transfert model**: atmospheric fields but also surface conditions

- **Data quality contrôle**: to reject cloudy/rainy data (AMSU-A Ch4: 52.3 GHz, AMSU-B Ch2: 150 GHz, SSMI/S Ch2: 52.3V and Ch8: 150 H)

- Other conditions : bias correction (Dee [2004], Aulligné et al. [2007]), good specification of observation and model errors, ….

On the need for a good knowledge of emissivity



Effect of the surface

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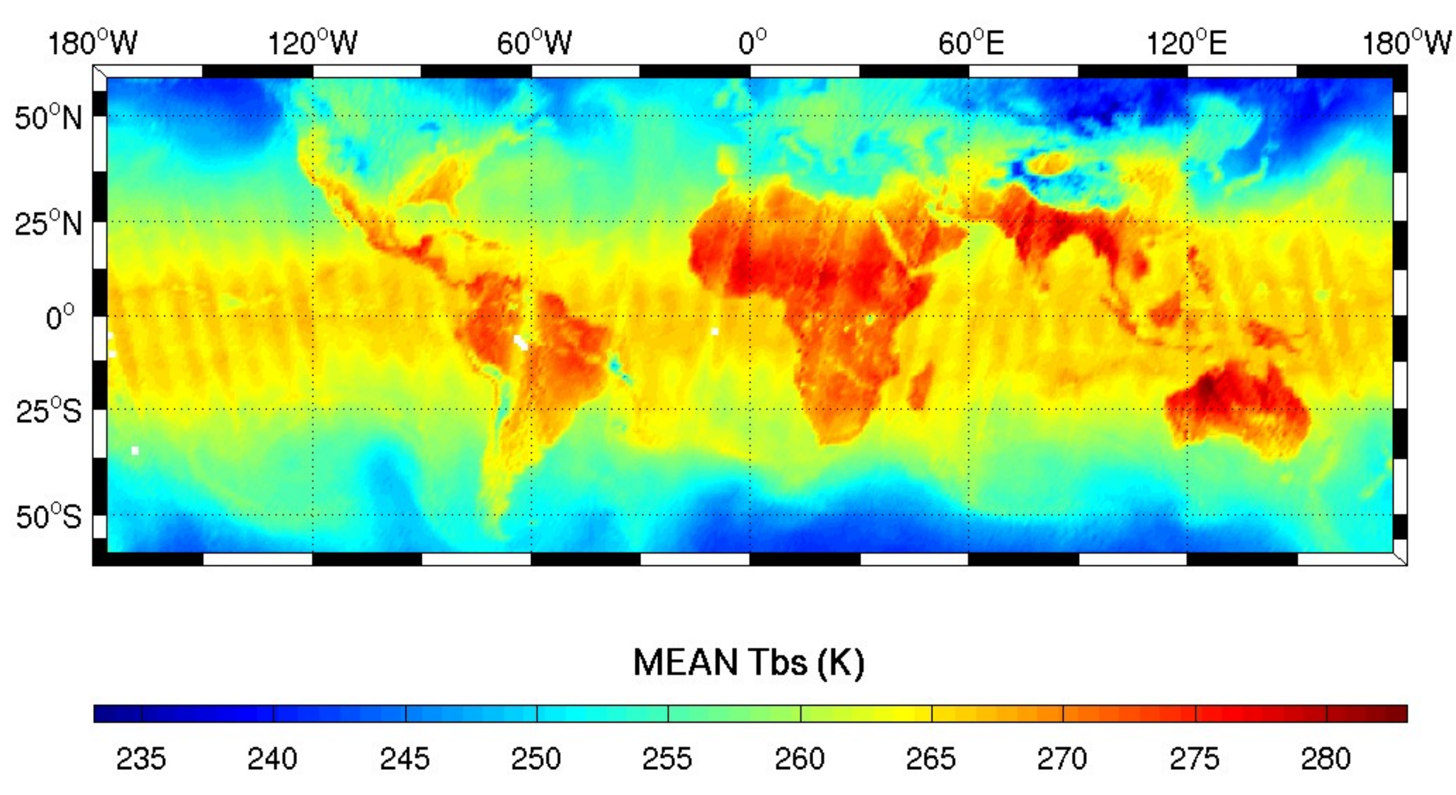
On the need for a good knowledge of emissivity

To assimilate surface sensitive channels: one should be able to separate the surface effect from the atmospheric signal

AMSU-A, ch4: 52.8 GHz, 08/04/2010



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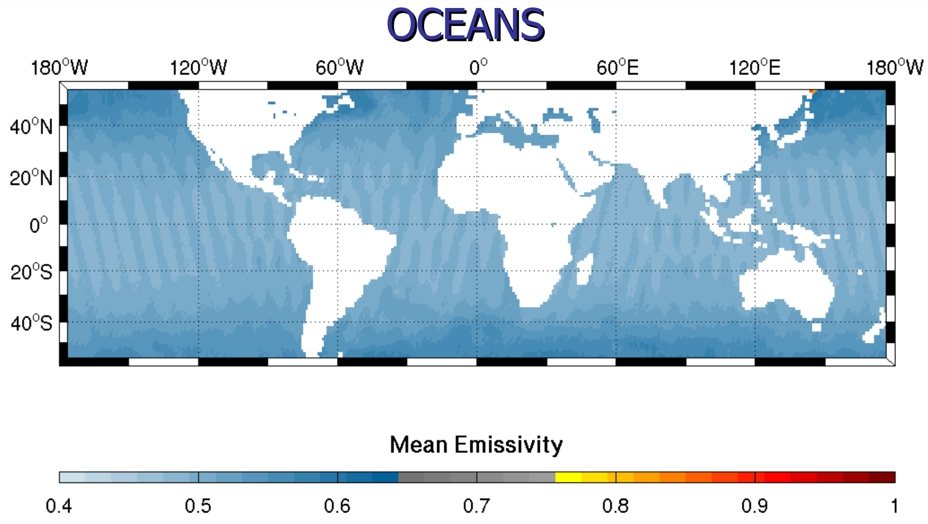
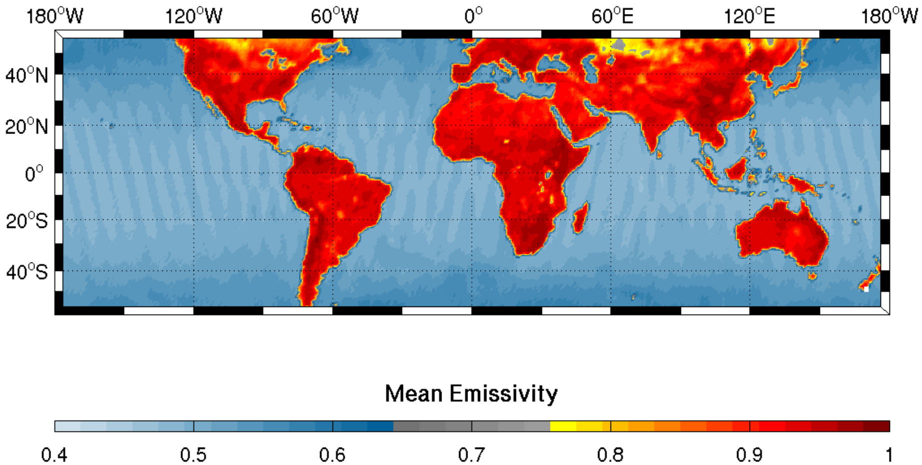


Emissivity ~ 0.5: the surface contribution to the measured signal < land surfaces

Assimilation: emissivity model Fastem (English, Hewison [1998], Deblonde, English [2000], Liu et al. [2010]) meets NWP requirements

On the need for a good knowledge of emissivity

OCEANS LAND



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Emissivity ~ 1: Higher contribution of the surface, complexe variations in space/time, surface conditions, type, …

Assimilation: Difficult

On the need for a good knowledge of emissivity

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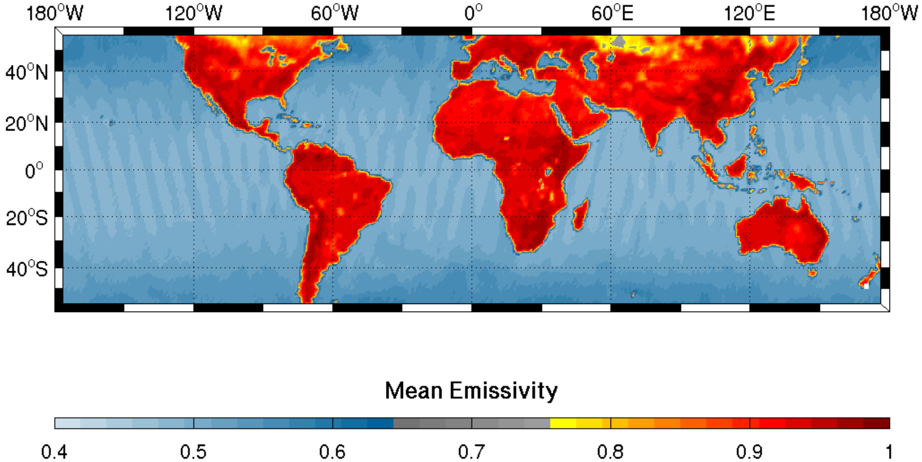

Emissivity ~ 0.5: the surface contribution to the measured signal < land surfaces

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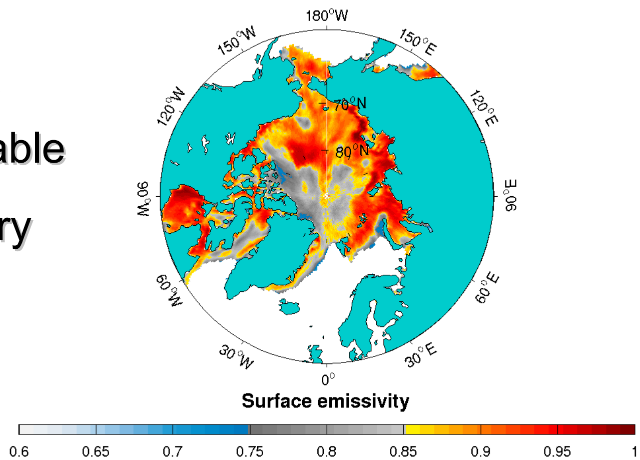
SEA ICE

Emissivity : very high, highly variable

Assimilation: Very difficile



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Assimilation: Difficult

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On the need for a good knowledge of emissivity

in-situ measurements

- Different surface types
- Calvet et al. (1995), Matzler (1994, 1990), Wigneron et al. (1997) ...

Airborne measurements

- different surface types (snow, forest)
- Hewison and English (1999), Hewison 2001, …

From satellites

- Regional to global scales
- Choudhury (1993), Felde and Pickle (1995), Jones and Vonder Haar (1997), Karbou et al. (2005), Morland et al. (2000, 2001), Prigent et al. (1997, 1998), omong others

Modeling

- Complexity of interactions between radiation and the environment
- Need for accurate input information about vegetation, soil moisture, soil roughness at a global scale.
- Grody (1998), Isaacs et al. (1989), Weng et al. (2001), …

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Variabilty factors of emissivity

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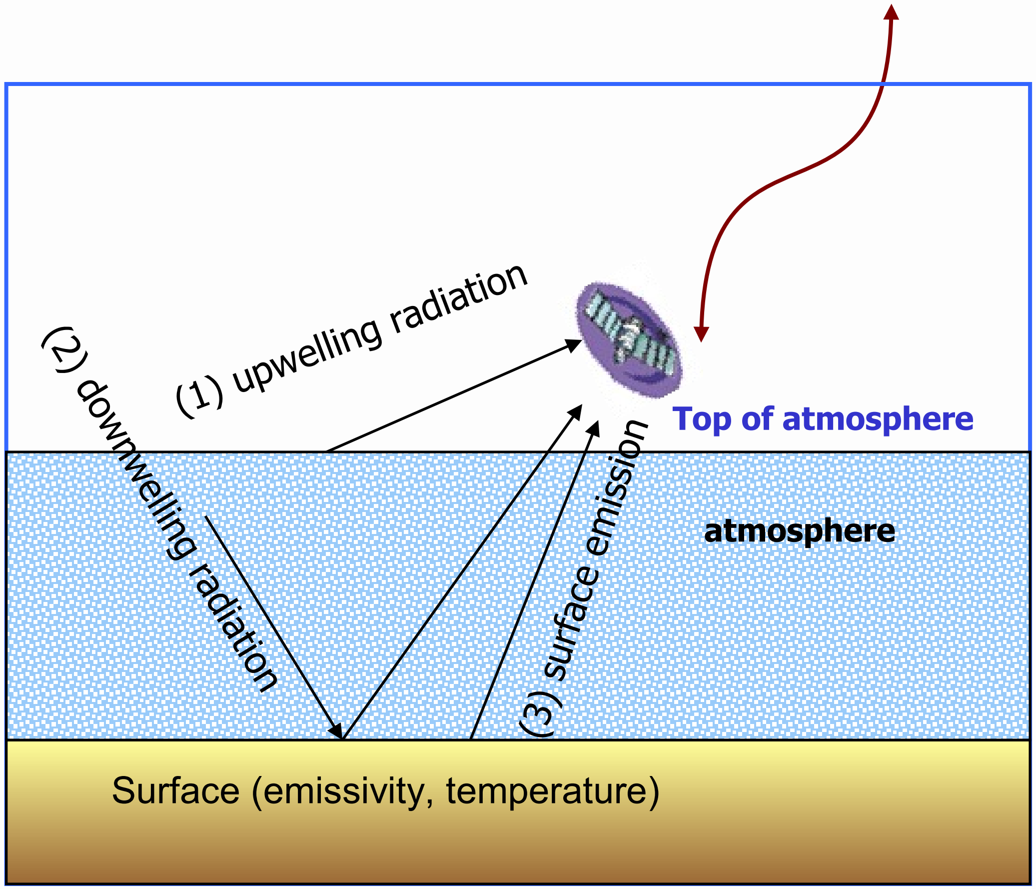
The variability factors of emissivity

Emissivity estimation using the radiative transfer equation

Under several assumptions

$$Tb = \underbrace{\varepsilon . Ts . \tau}_{(3)} + \underbrace{(1 - \varepsilon) . \tau . T(\downarrow)}_{(2)} + \underbrace{T(\uparrow)}_{(1)}$$



ill posed problem : large incertainties about the surface and the atmosphere

==> RTTOV +
T/Q profiles (short range forecasts, analyses, reanalyses) +
Ts (IR retrievals /short-range forecasts, analyses)

Emissivity estimation:

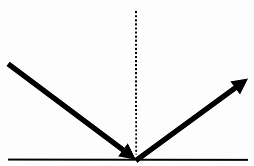
$$\varepsilon = \frac{Tb - T(\uparrow) - T(\downarrow) \times \tau}{\tau \times (Ts - T(\downarrow))}$$

surface approximation: usually specular

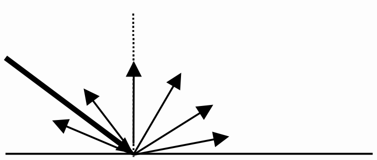
Questionable for near-nadir observations ? (Matzler, 2005)

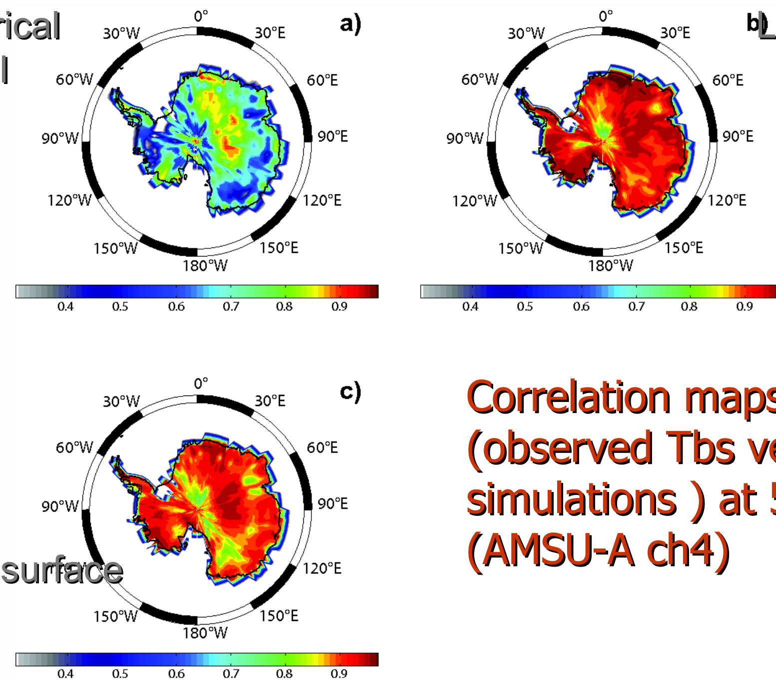
specular approximation for snow-free surfaces (Karbou et Prigent, 2005)

specular



lambertian





Correlation maps (observed Tbs versus simulations) at 52 GHz (AMSU-A ch4)

Guedj et. al. 2010: Sensitivity studies over Antarctica with 5 surface approximations

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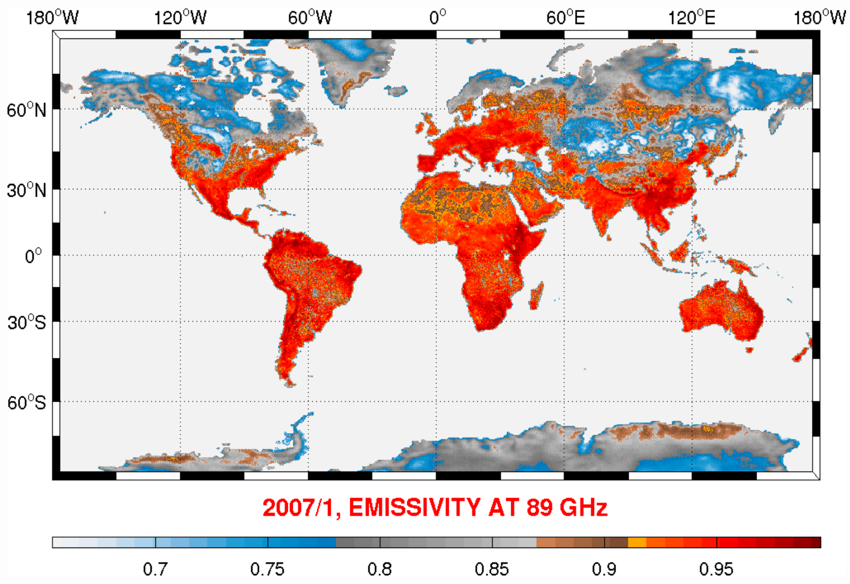
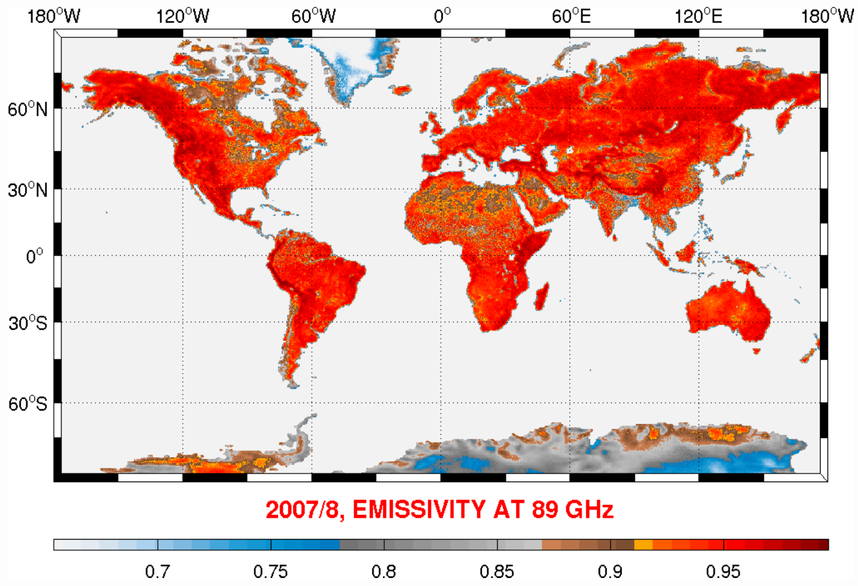
The variability factors of emissivity

Emissivity highly variable: surface types, in time, frequency, observation angle …

January



August



AMSU-A 89 GHz

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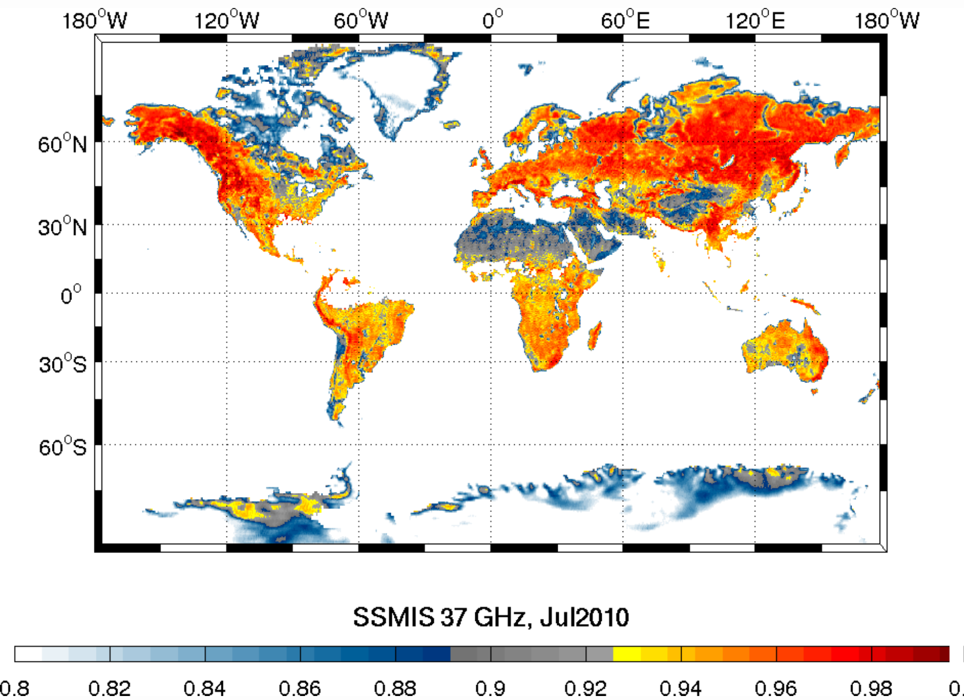
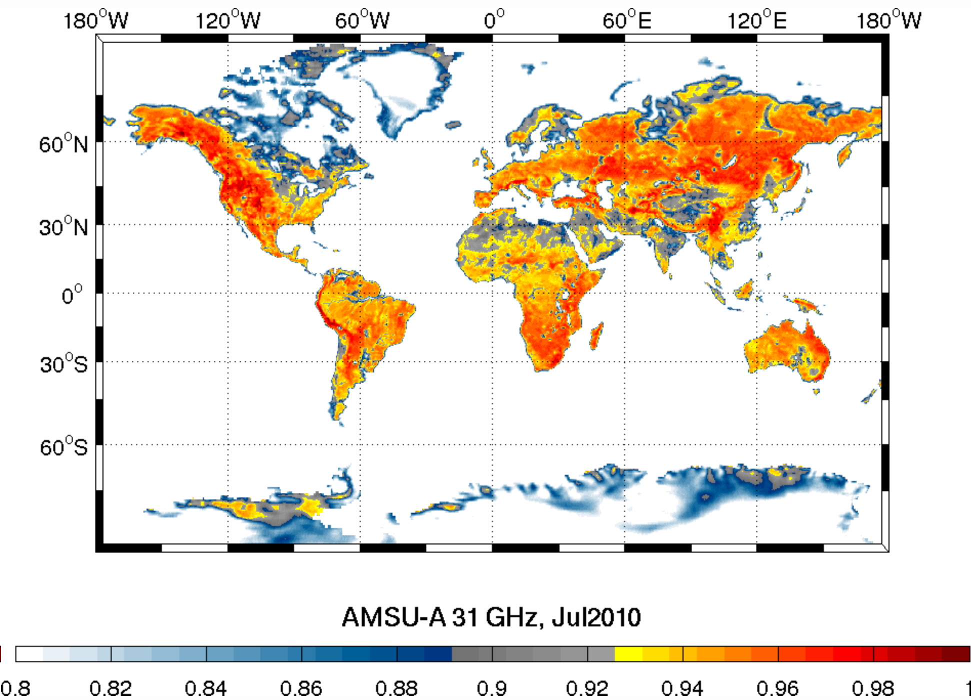
July 2010

SSMI/S, 37 GHz (V+H)/2



AMSU-A, 31 GHz



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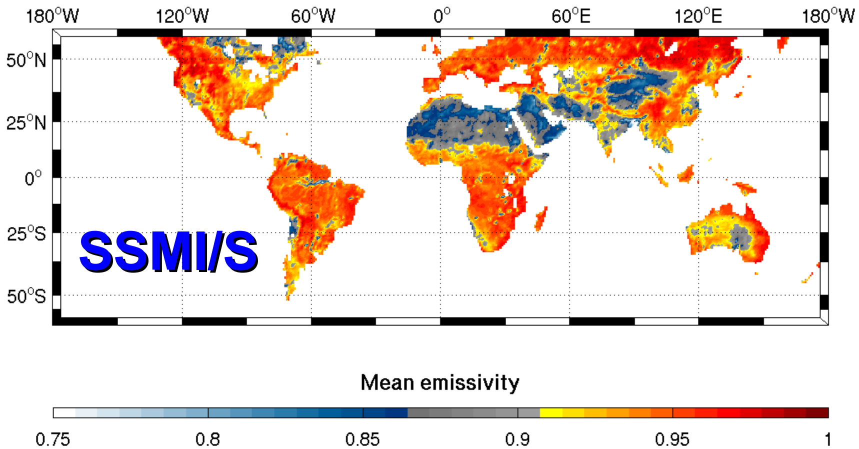
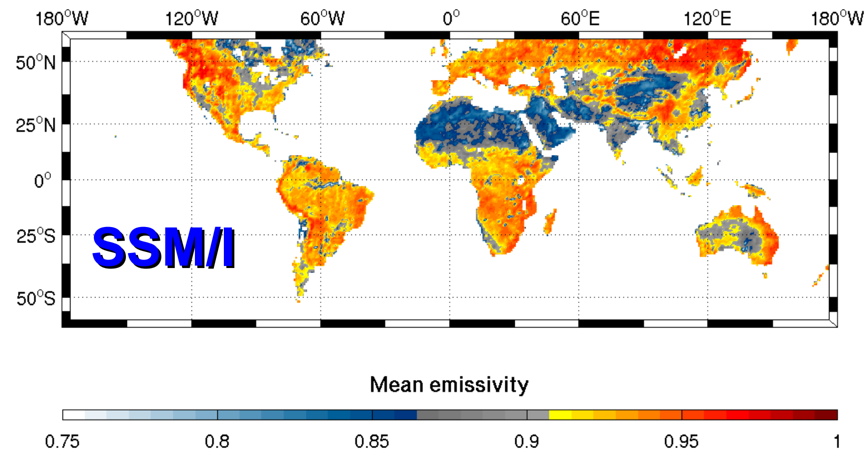
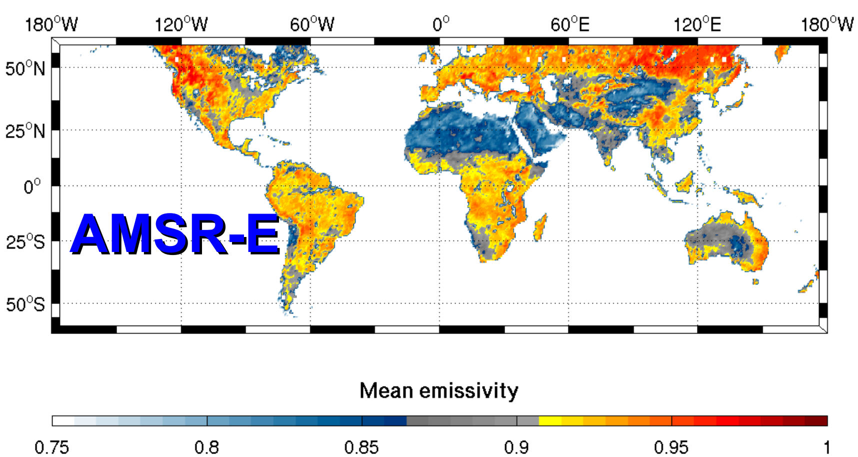
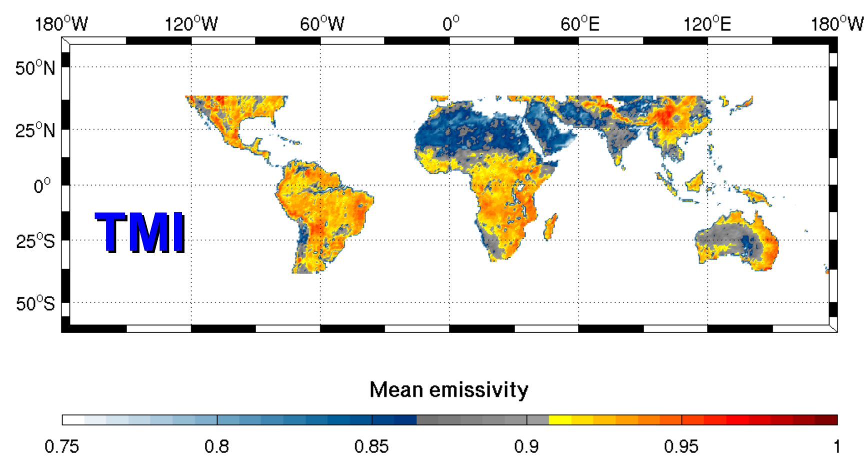




37 H GHz, August 2009



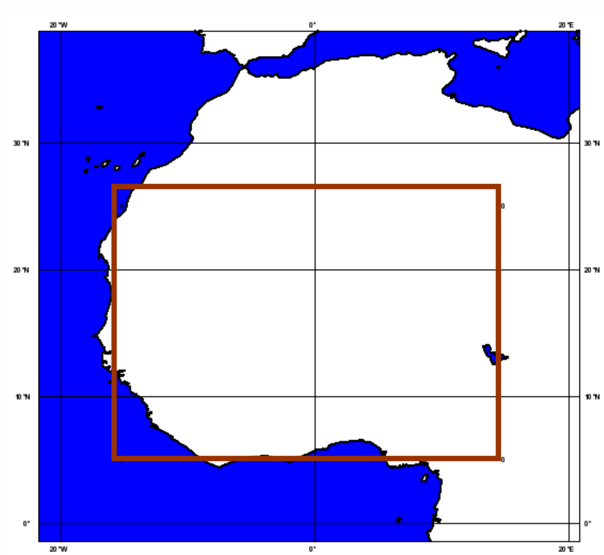


The variability factors of emissivity

<u>Emissivity varies</u> with surface condition (rain, snow, …) vegetation

2007, time step 10 days

- AMSU, SSM/I emissivities
- vegetation (NDVI)
- CPC rainfall



A. Daudin, F. Karbou

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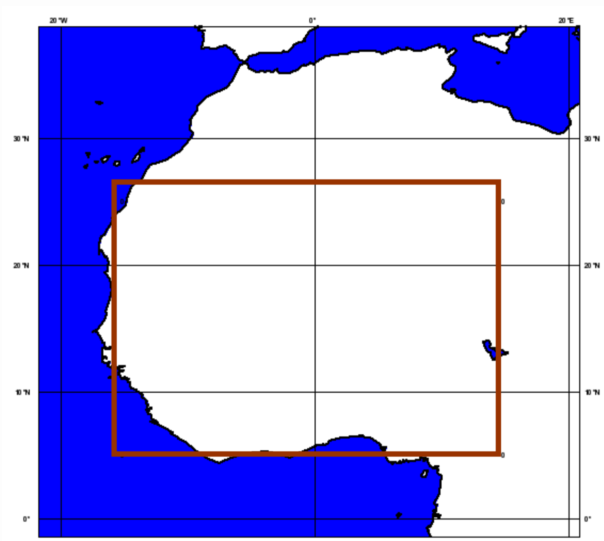

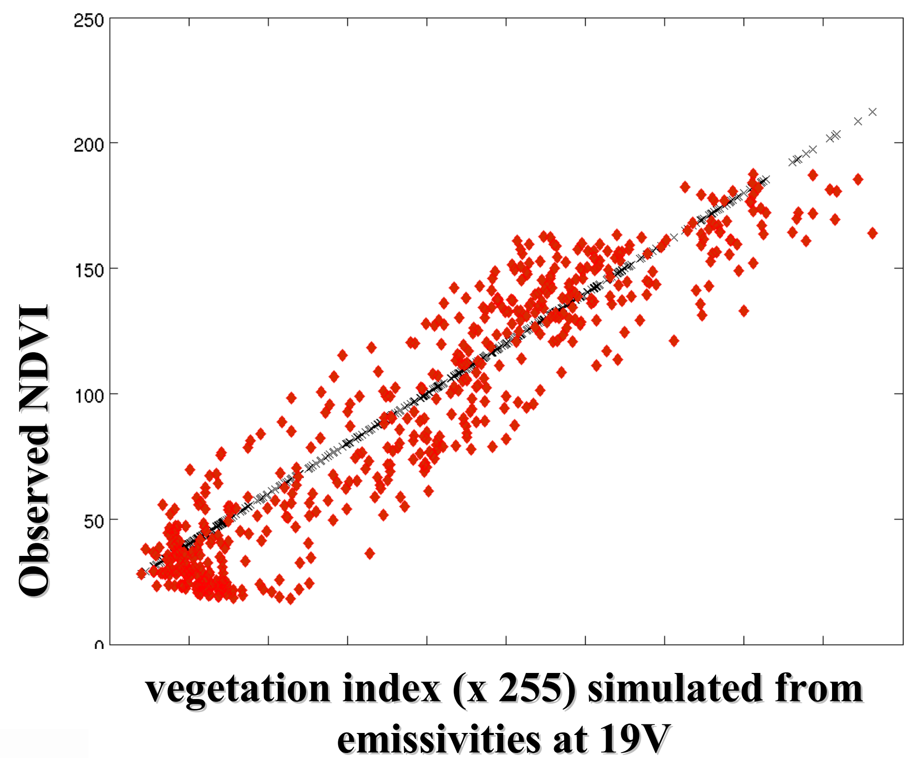

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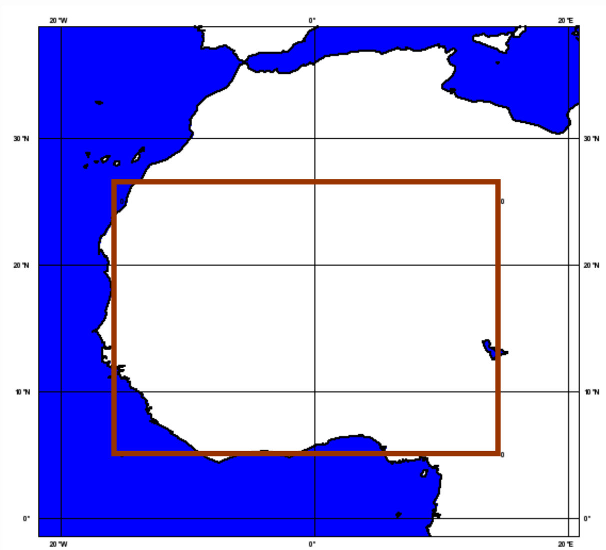

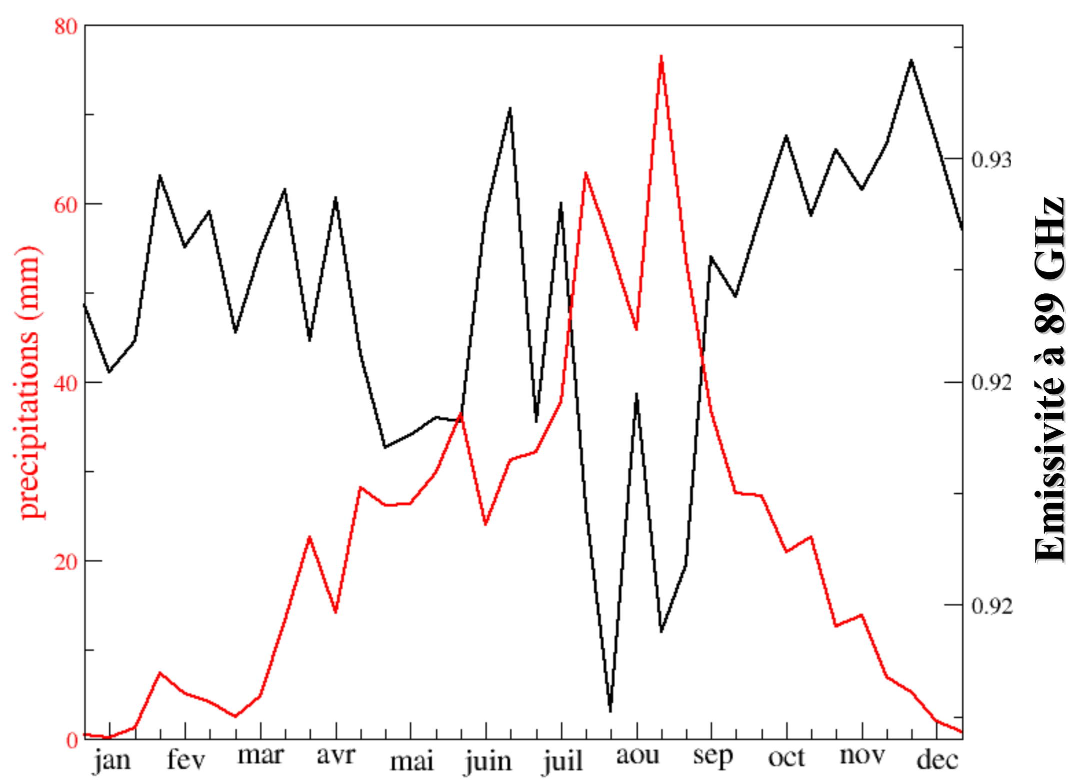

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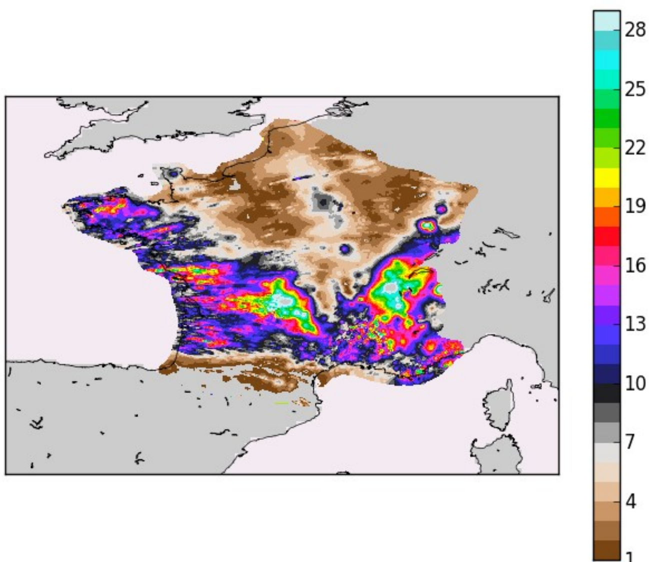
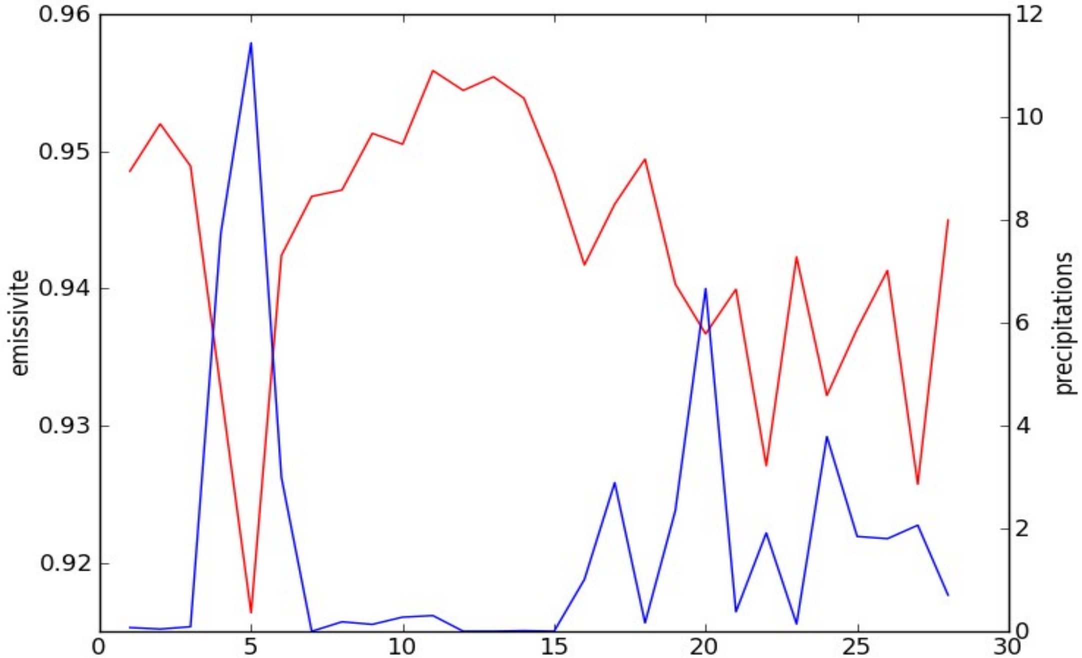


Antilope rain rate

89GHz emissivity versus rain



C. Birman, F. Karbou, J-F. Mahfouf

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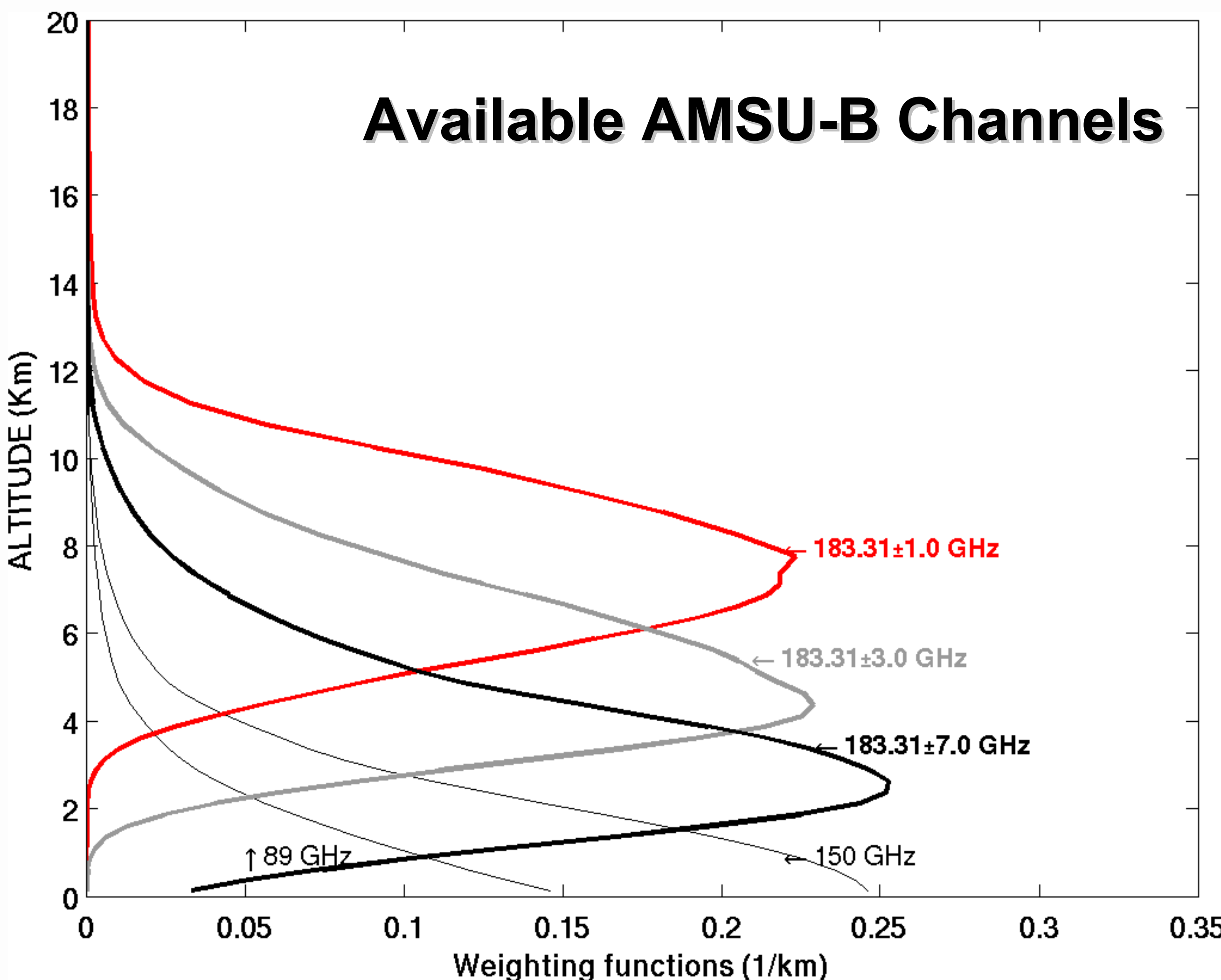
Indirect vertical measurements of temperature and humidity:



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Use of microwave data over land

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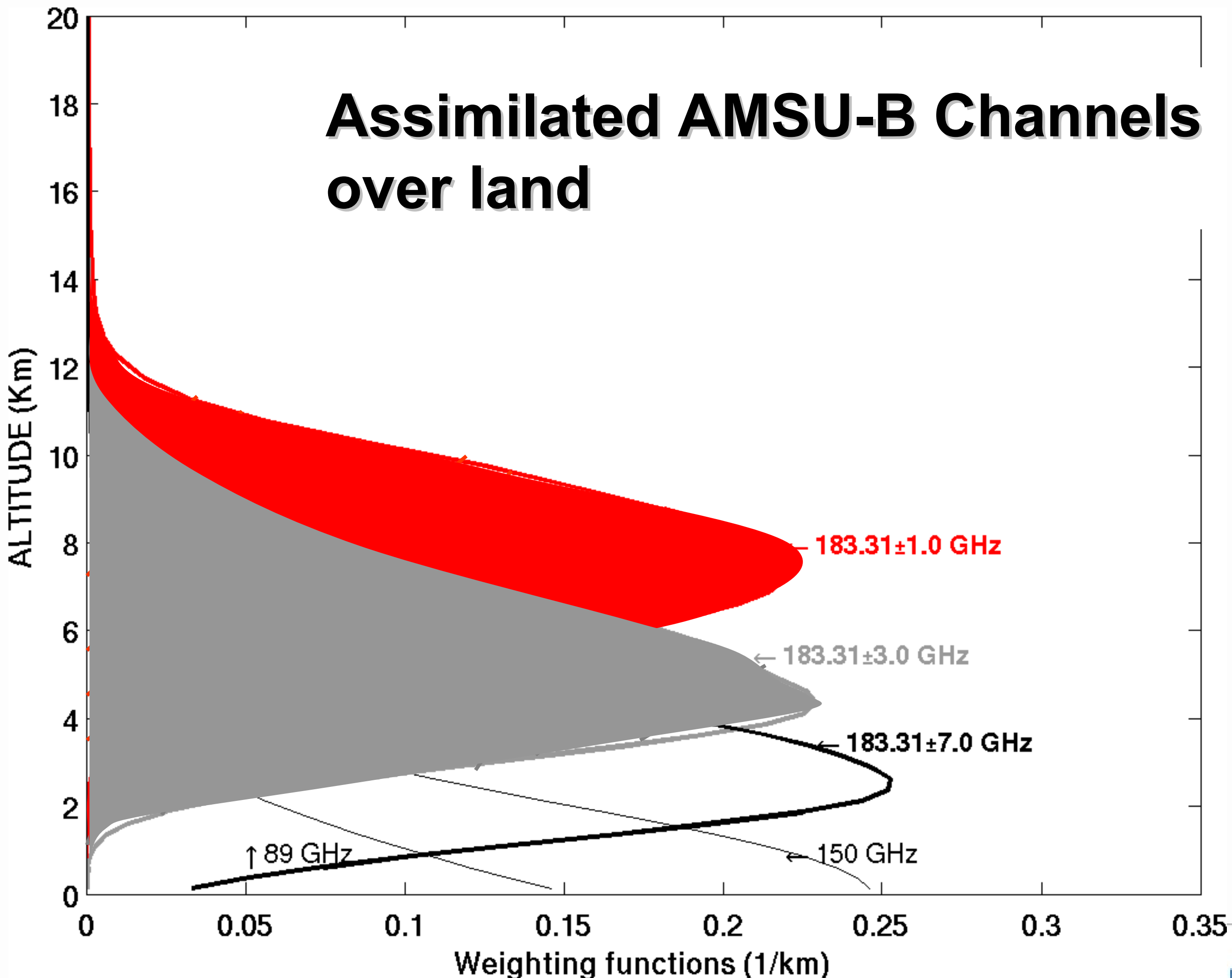

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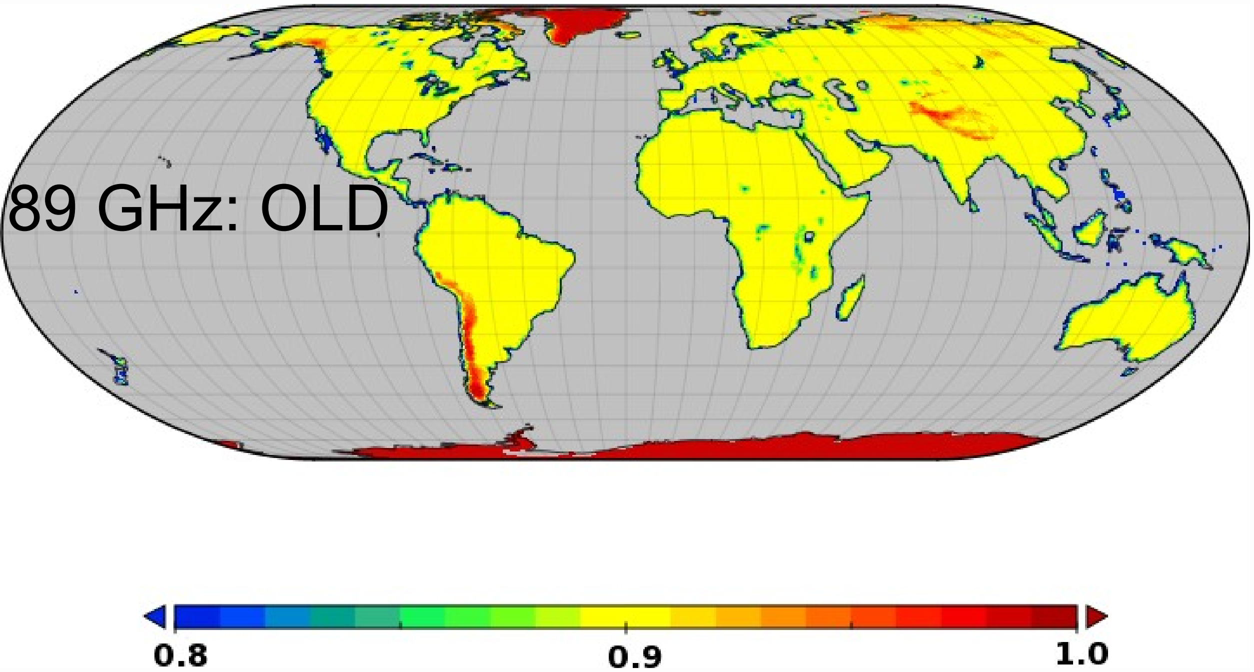

Land surface emissivity : regression version of models
➔ eased the assimilation of sounding channels

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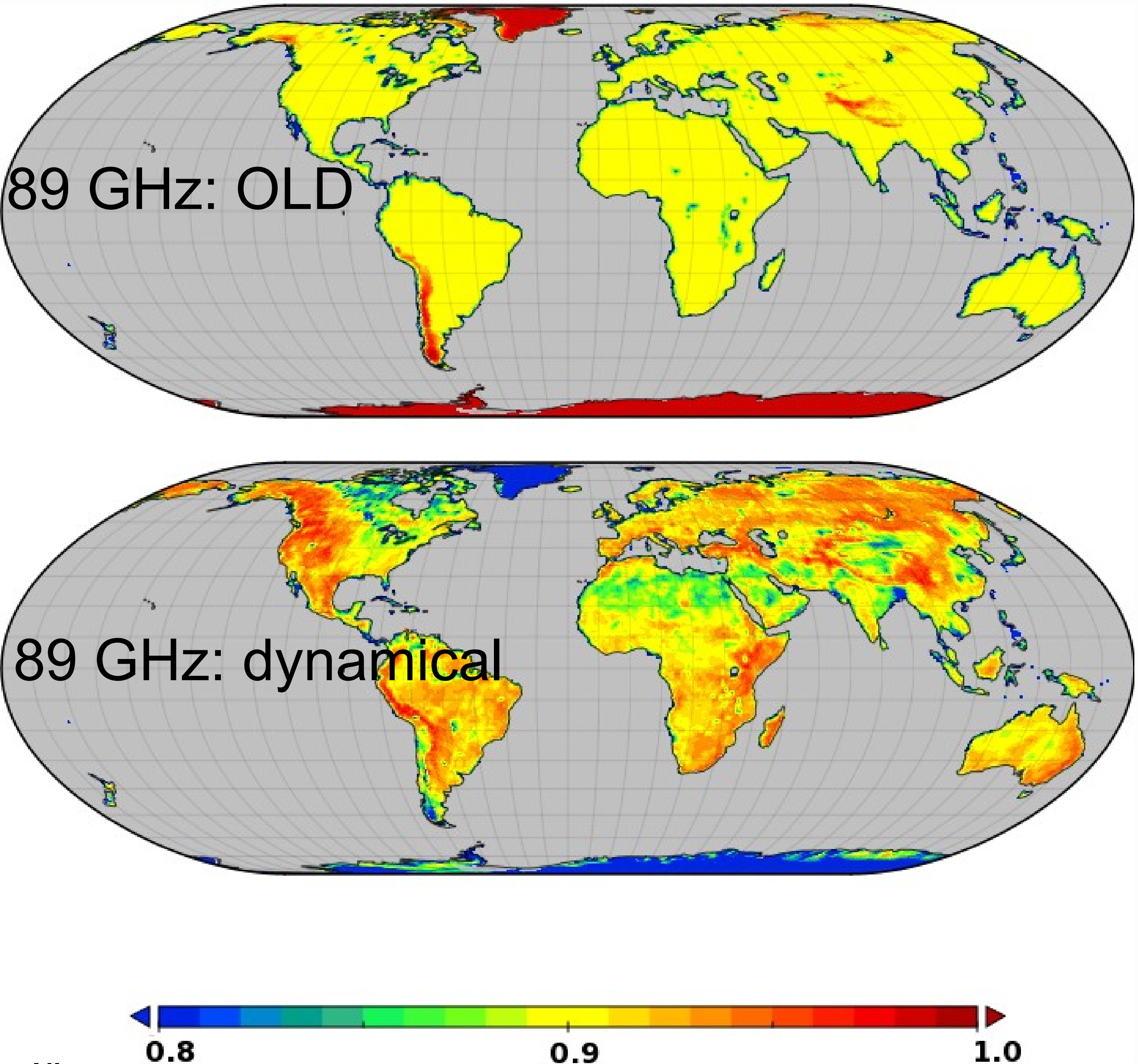

Land surface emissivity : regression version of models
➔ eased the assimilation of sounding channels

Since July 2008, operational implementation of a new land surface emissivity parameterization (Karbou et al. 2006)

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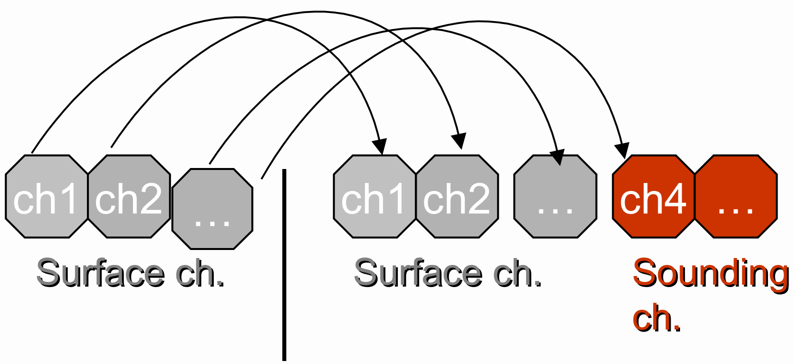
Use of microwave data over land

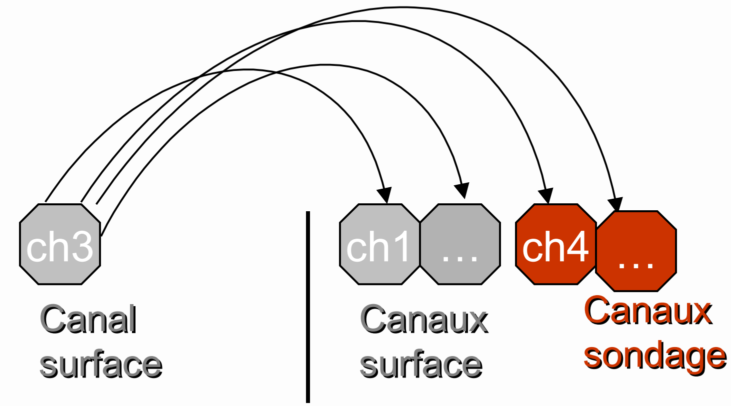
Two possible strategies: « climatology » ou « dynamical »

Emissivity atlases



- the angular variation of emissivity
- pb. if there is a surface change (rain, snow)
- But could be used to retrieve Ts (Guedj et al. 2011)

Calcul instantané de l'émissivité à un canal fenêtre



- the best surface ch. : the closest in frequency or the most sensitive to the surface ?
- Surface changes + observation angle variation are taken into account

Use of microwave data over land

« dynamical land emissivity model » operational in ARPEGE since July 2008

- Interfaced with RTTOV (Eyre 1991; Saunders et al. 1999; Matricardi et al. 2004)

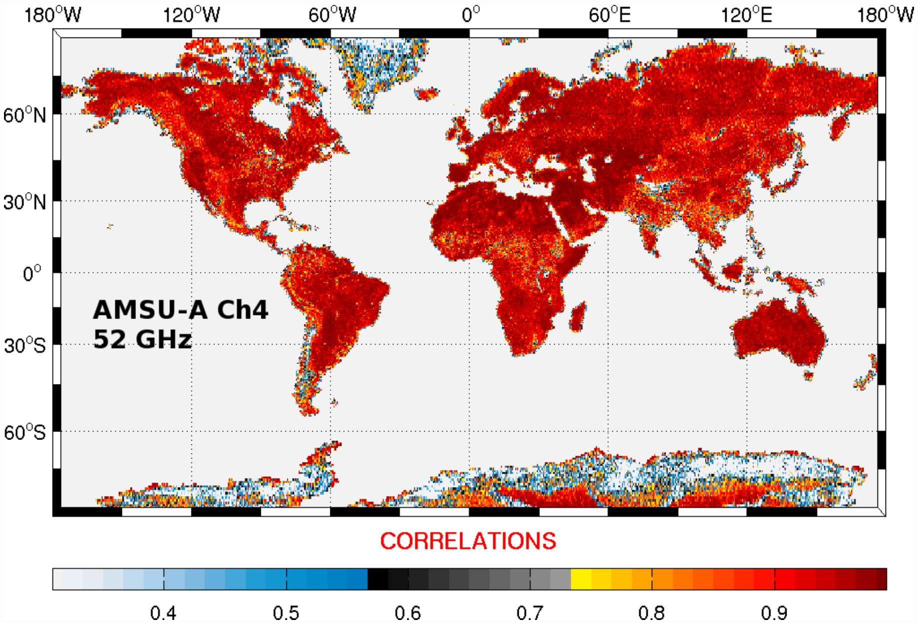
- Land emissivity is computed from selected surface channels (AMSU-A ch3 (50 GHz) and from AMSU-B ch1 (89 GHz))

- Emissivity is dynamically updated for each atmo. & surface situations

Use of microwave data over land

Correlations between Obs and RTTOV Sim., AMSU-A ch4, August 2006

CTL



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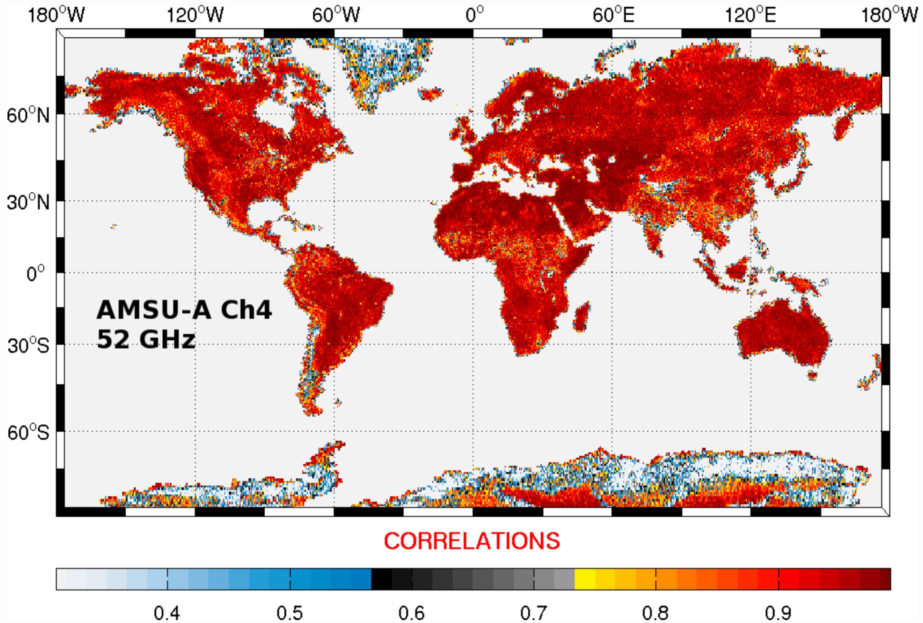
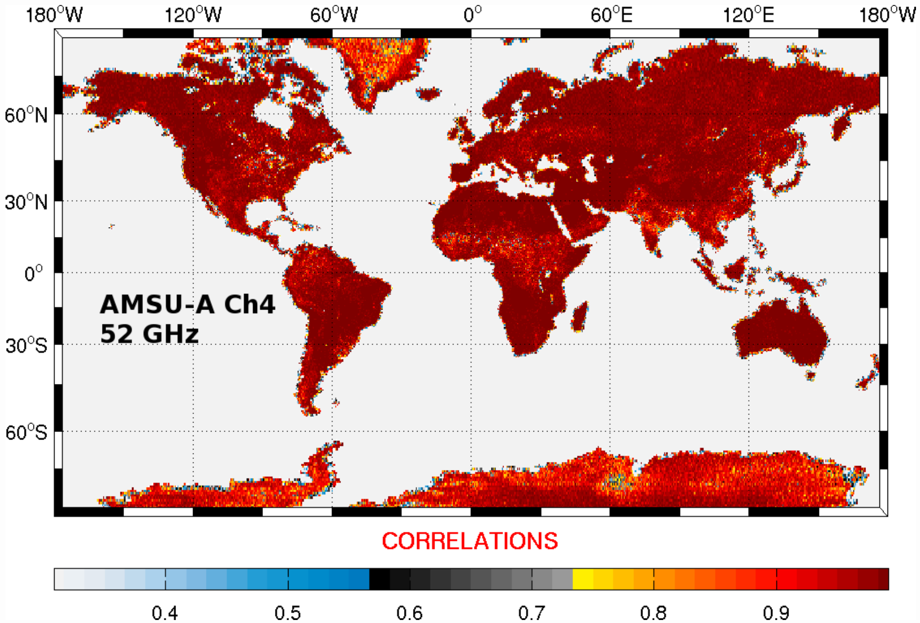


CTL + dynamical emis.



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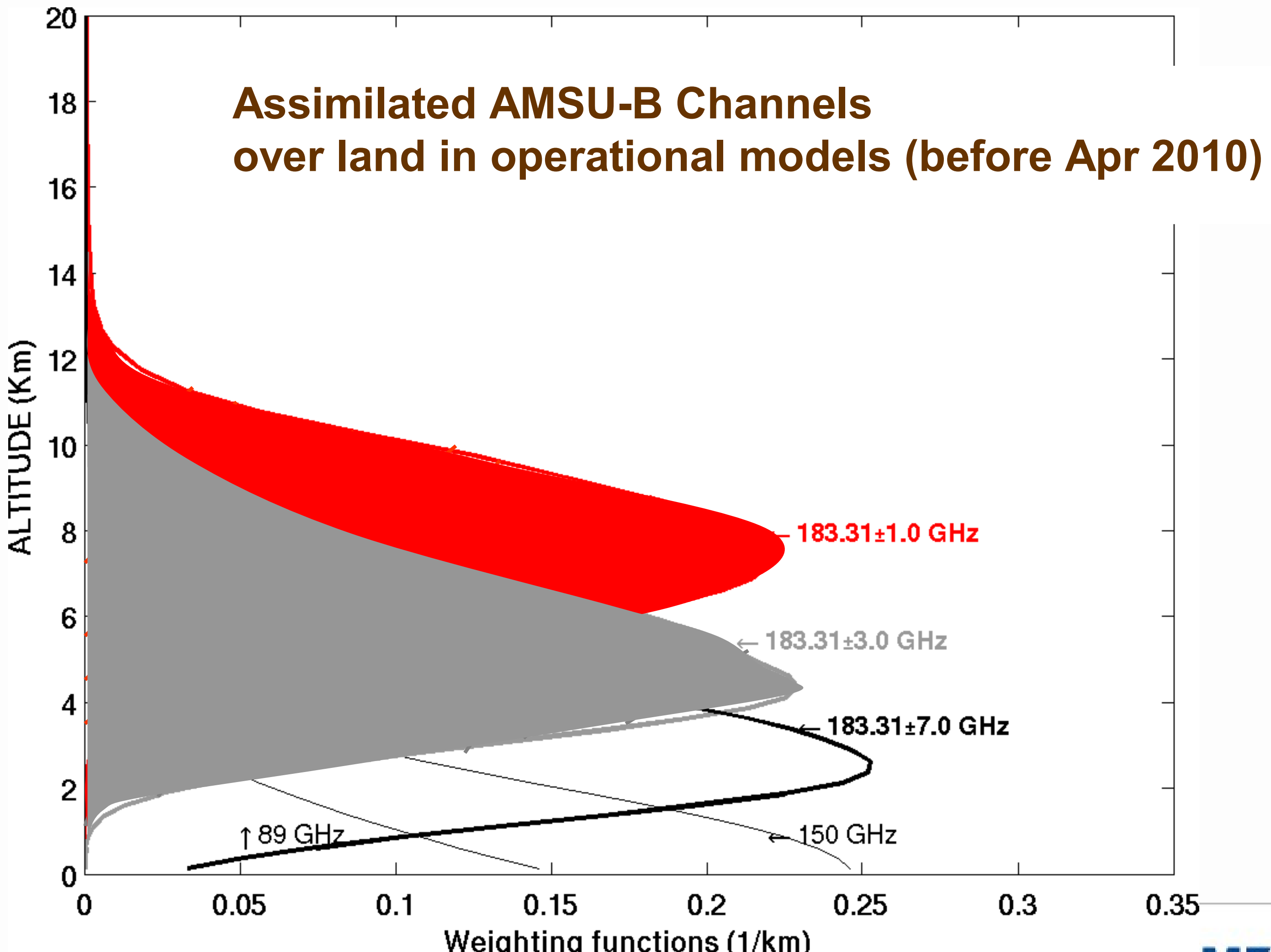
Use of microwave data over land

- Sounding channels: to assimilate as many observations over land as over sea
- Make it possible to assimilate surface sensitive channels from AMSU over land

Use of microwave data over land



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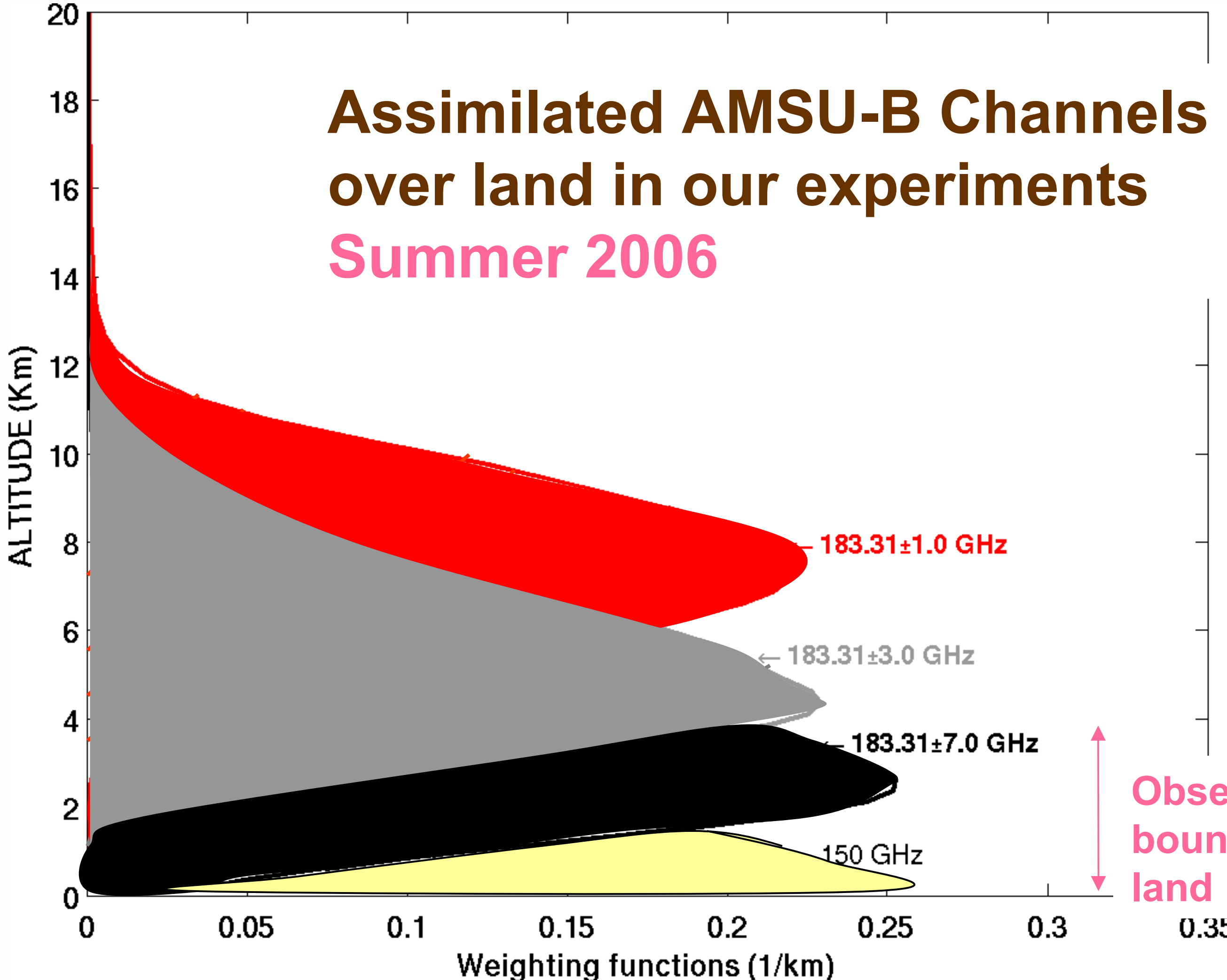
Use of microwave data over land



Observations of the boundary layer over land

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Use of microwave data over land

Main results when AMSU surface channels are assimilated in 4D-Var:

- Forecast errors with respect to radiosondes and ECMWF analyses

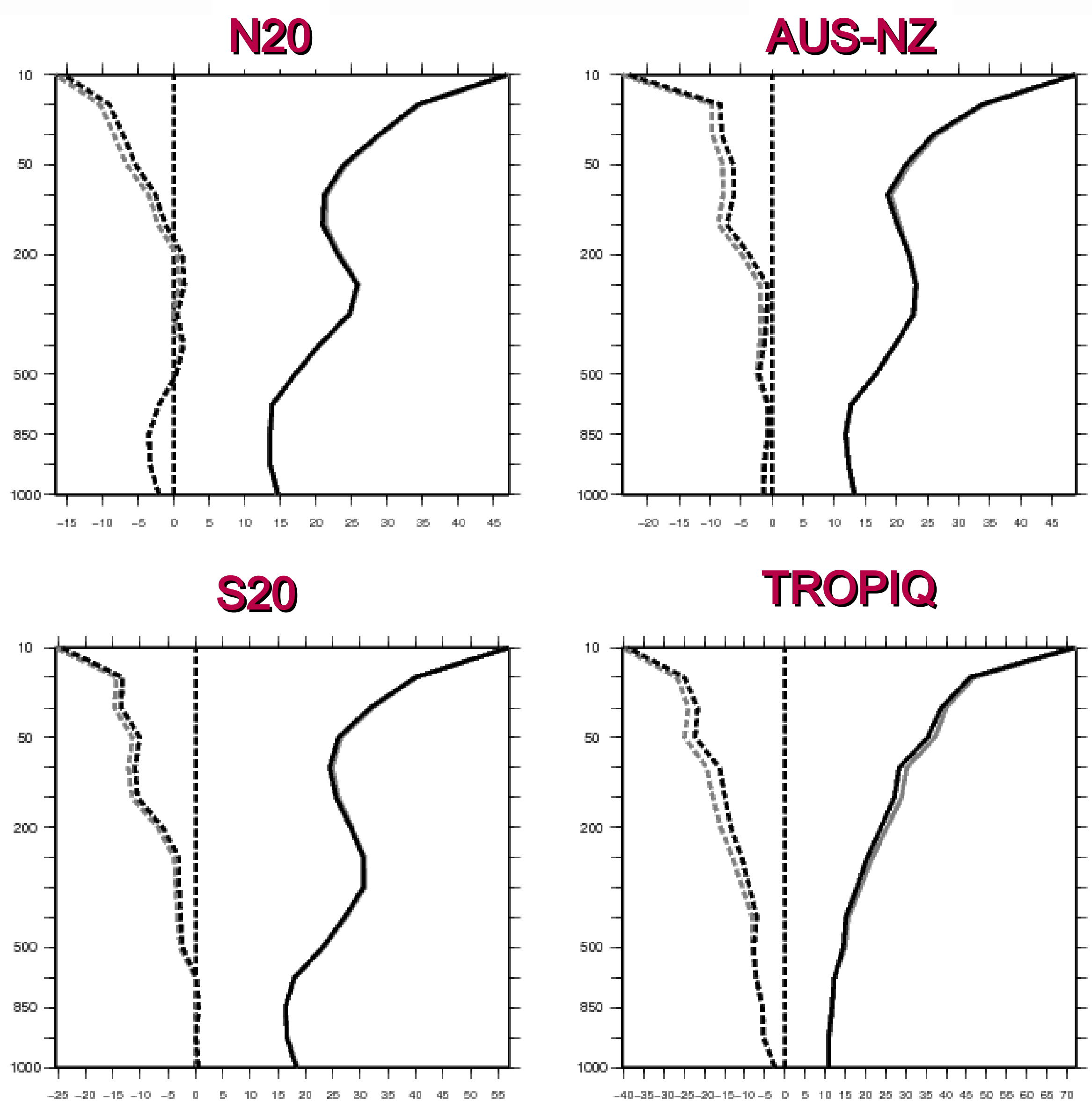
- Impact on analysis of humidity, evaluation against independent GPS measurements from AMMA network

Use of microwave data over land

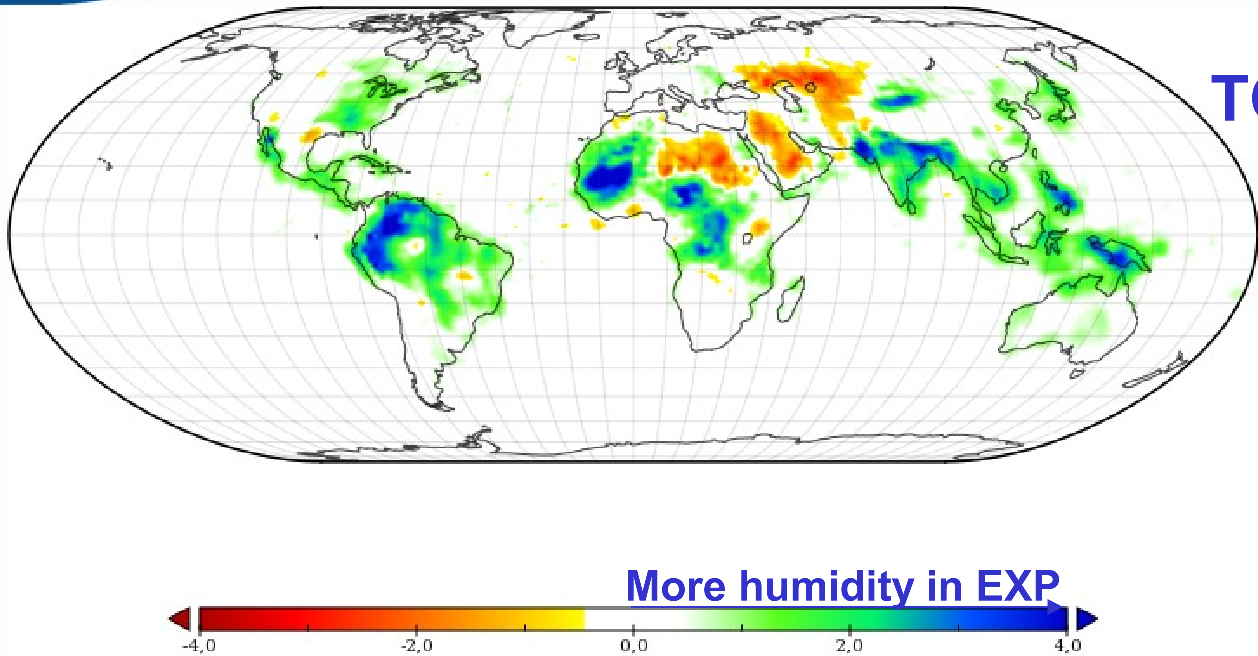
Scores geopotential height / Radiosondes, 48h, 1 month

CTL --- BIAS
__ RMSE

EXP --- BIAS
__RMSE



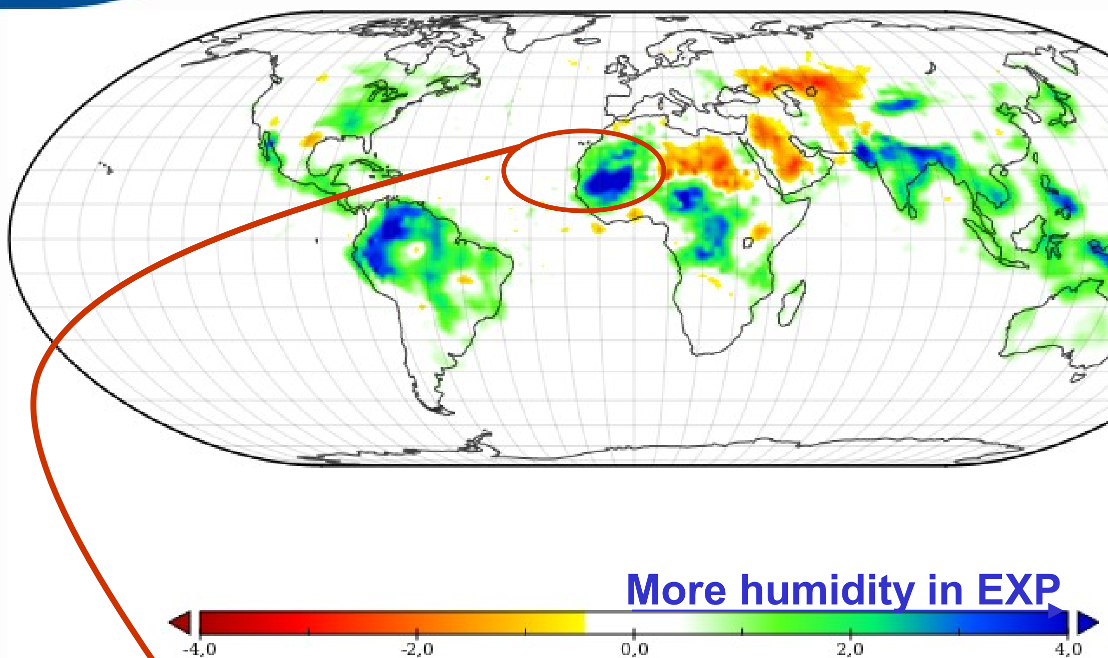
Use of microwave data over land



TCWV (EXP-CTL)

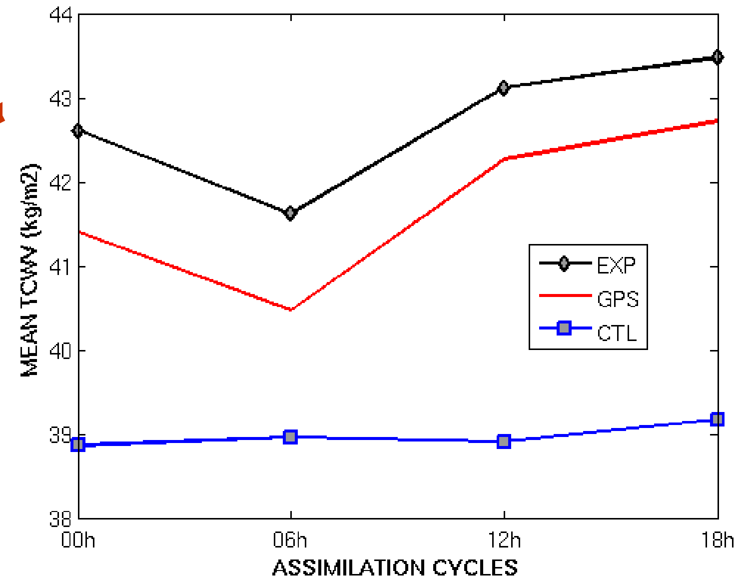
Similar humidty features observed when assimilating TCWV from ENVISAT MERIS over land in IFS (Bauer, 2009)

Use of microwave data over land



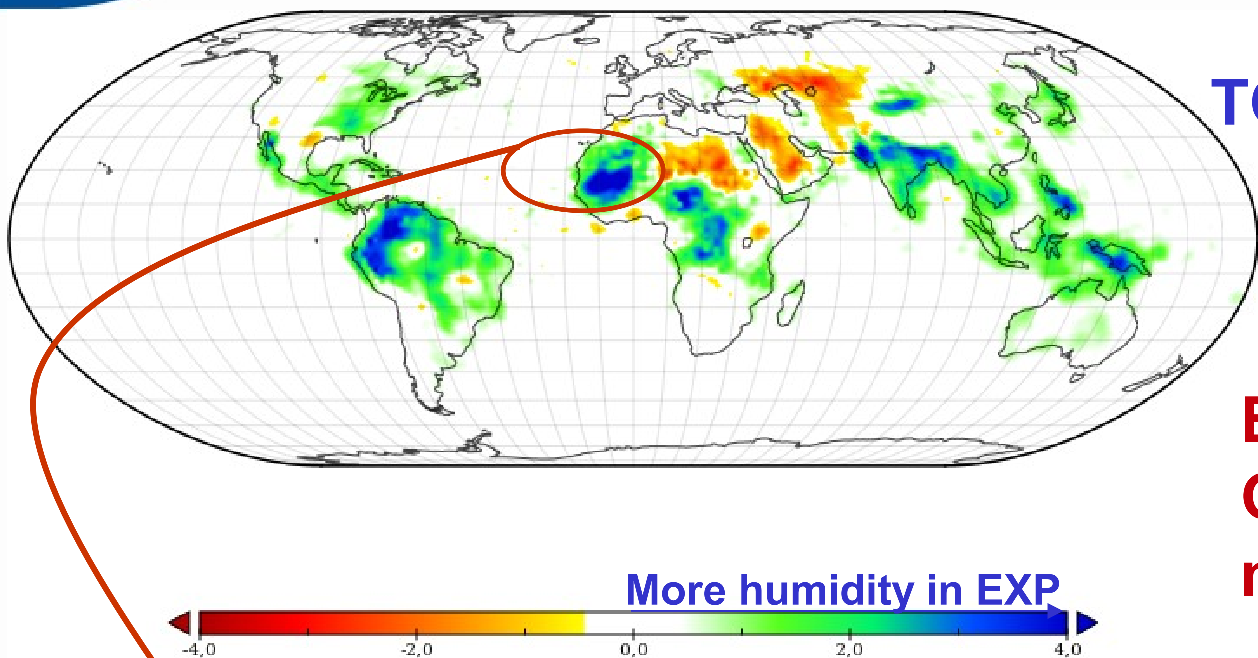
TCWV (EXP-CTL)

Evaluation against GPS measurements



TCWV diurnal cycle, Timbuktu (MALI)

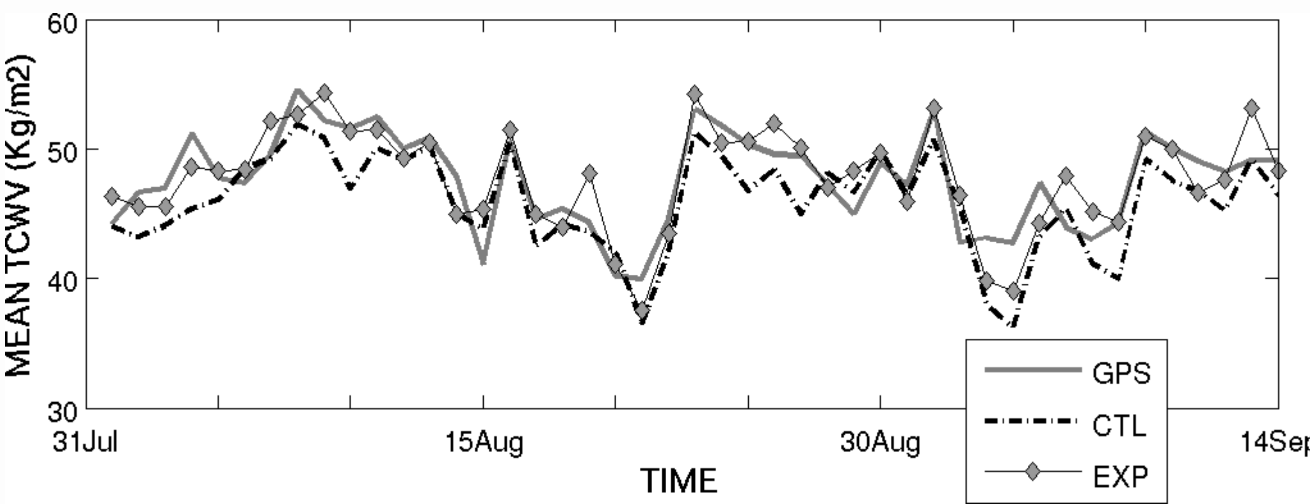
Use of microwave data over land



TCWV (EXP-CTL)

Evaluation against GPS measurements

TCWV daily time series, Ouagadougou



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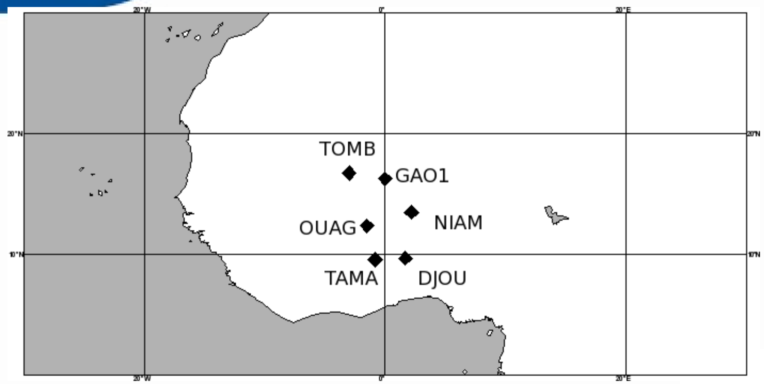
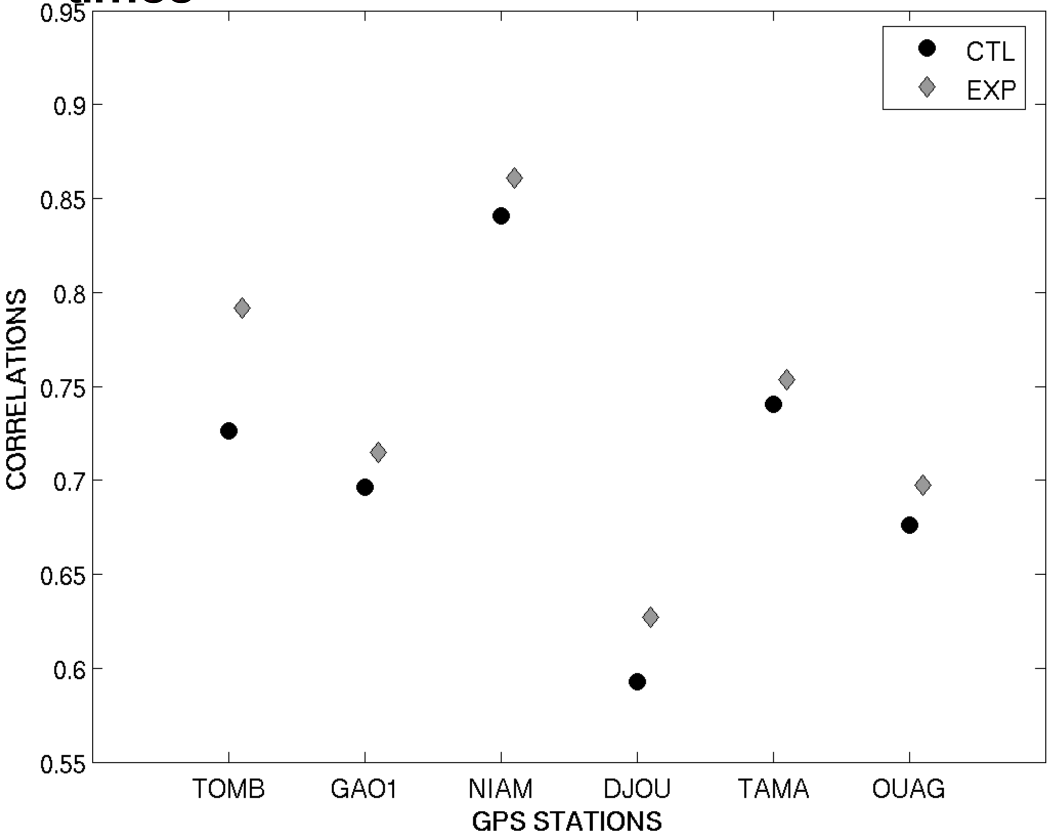
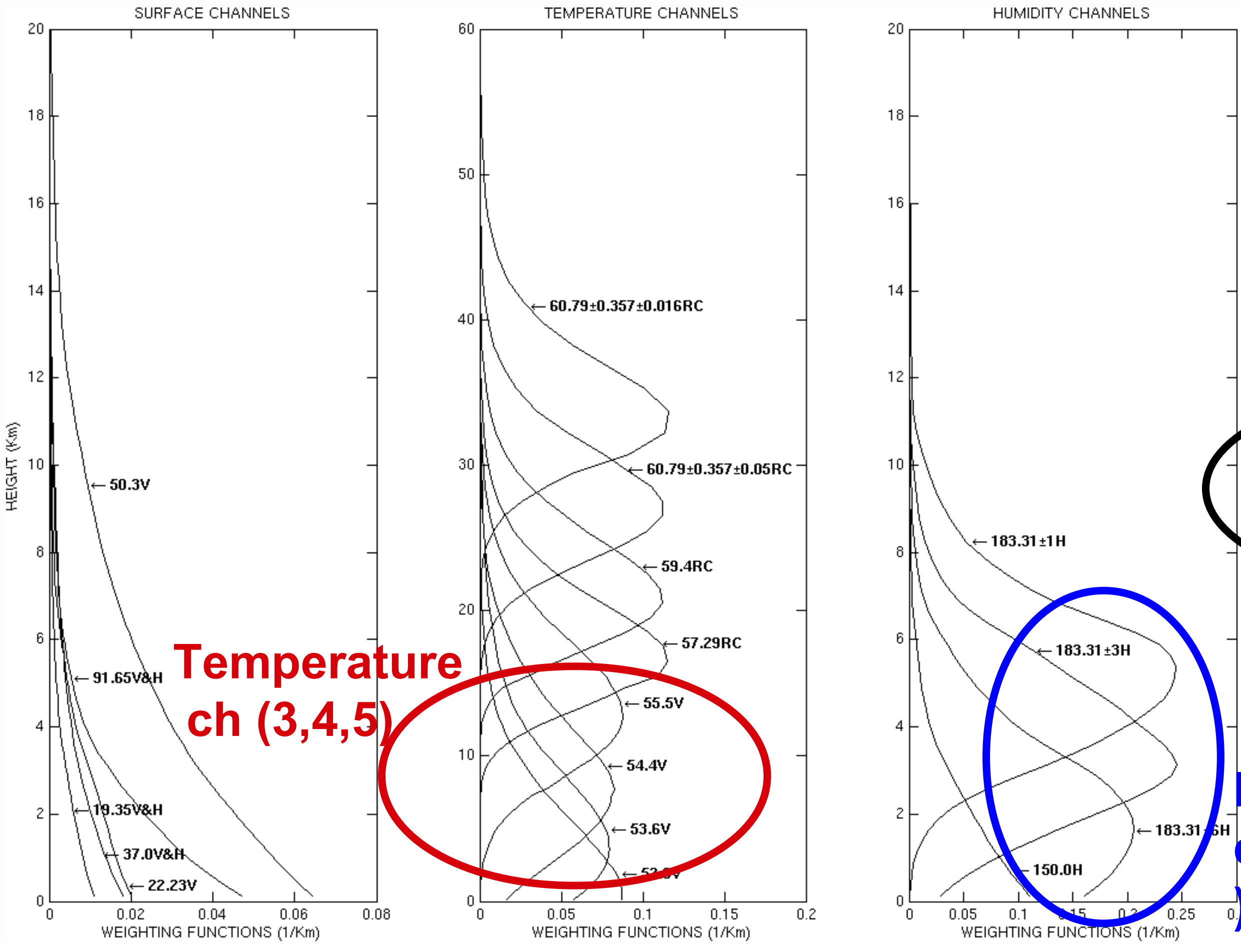
Use of microwave data over land



Correlations with GPS, 45 days, synoptic times



Feasability studies to assimilate some SSMI/S sounding channels



Humidity ch(9,10,11)

SSMI/S:

- conical scanning: fixed observation angle (53°)

- Polarisation: V and/or H

- Window channels:
19.35 V&H, 22.23 V, 37 V&H, 50.3 V, 91.65 V&H GHz

Over sea

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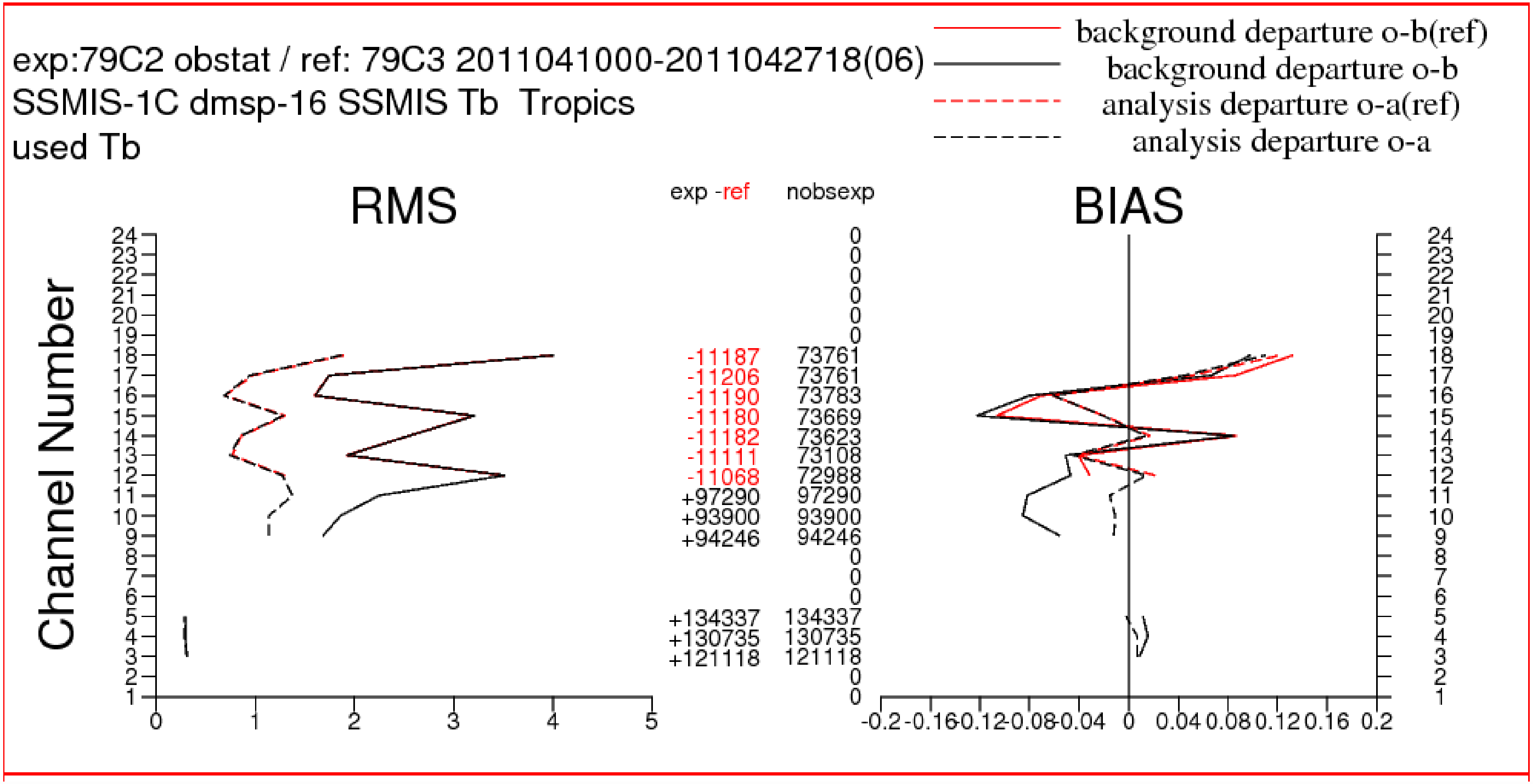
Use of microwave data over land

Emissivity (~183 GHz) = Emissivity at 91H GHz (ch18)
Emissivity (~54-60 GHz) = Emissivity at 50V GHz (ch1)

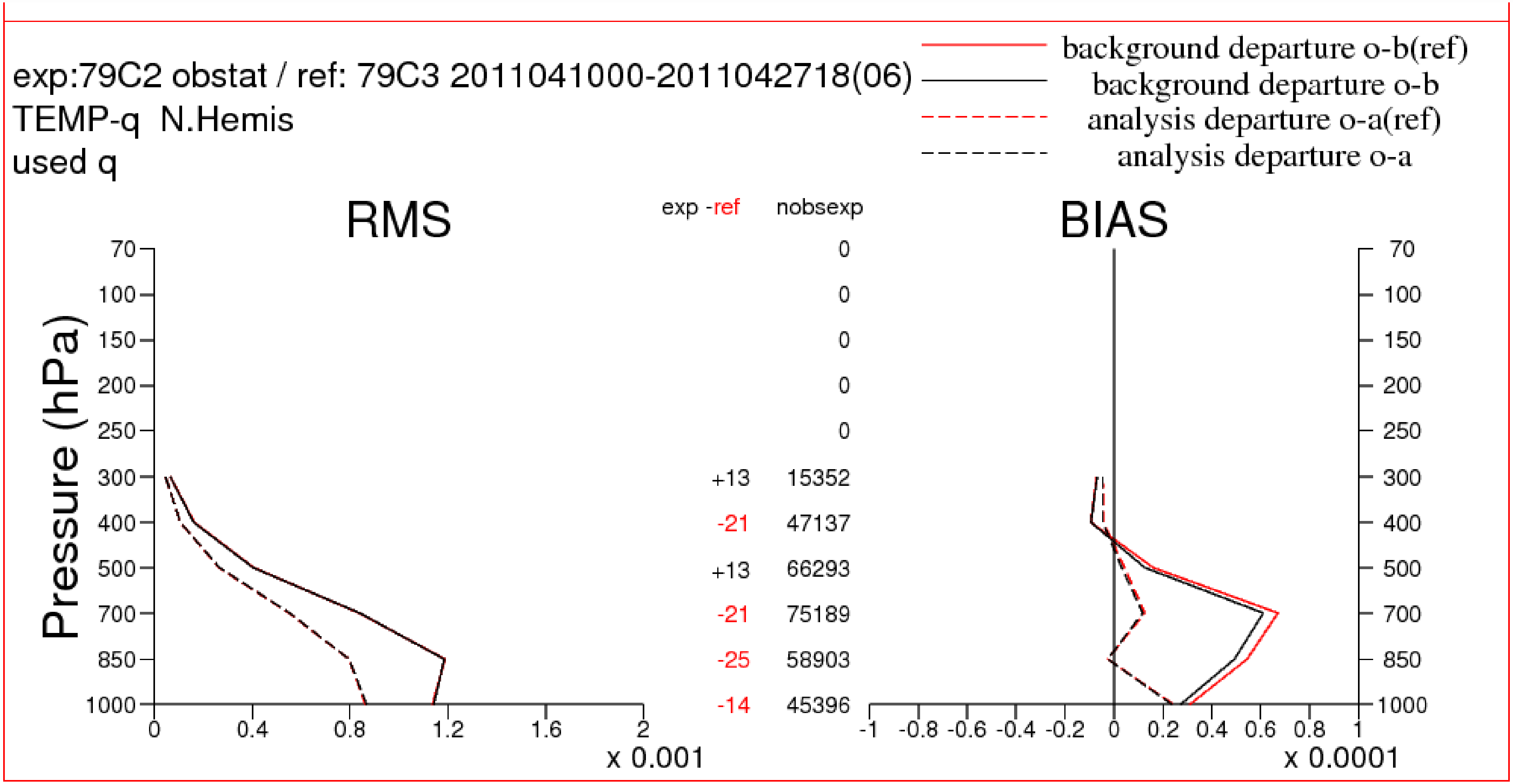
Data impact studies for evaluation:

- **Period: 01/04/2011 to 29/05/2011**
- **CTL: the current operational system**
- **EXP: CTL + assimilation of SSMIS channels 3-5 & 9-11 over sea and land**
- **Data from DMSP-16 and -17**
- **Quality control: SSMIS ch2 (52V, 0.7K) and SSMIS ch8 (150H, 2.7K)**
- **Obs error: 0.5K & 2K**

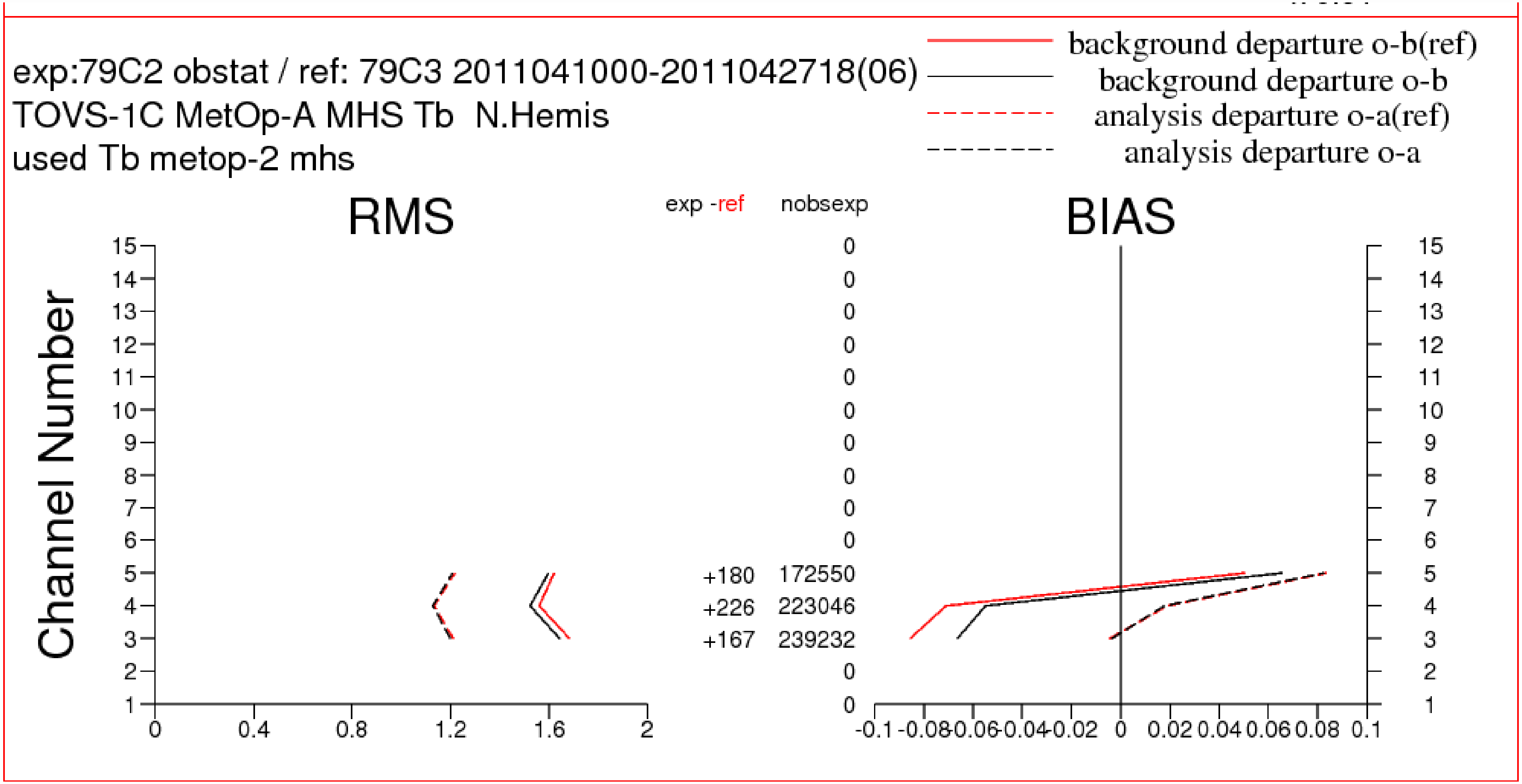
Fit to observations : SSMIS



Fit to observations : Radiosondes



Fit to observations : AMSU-B/MHS



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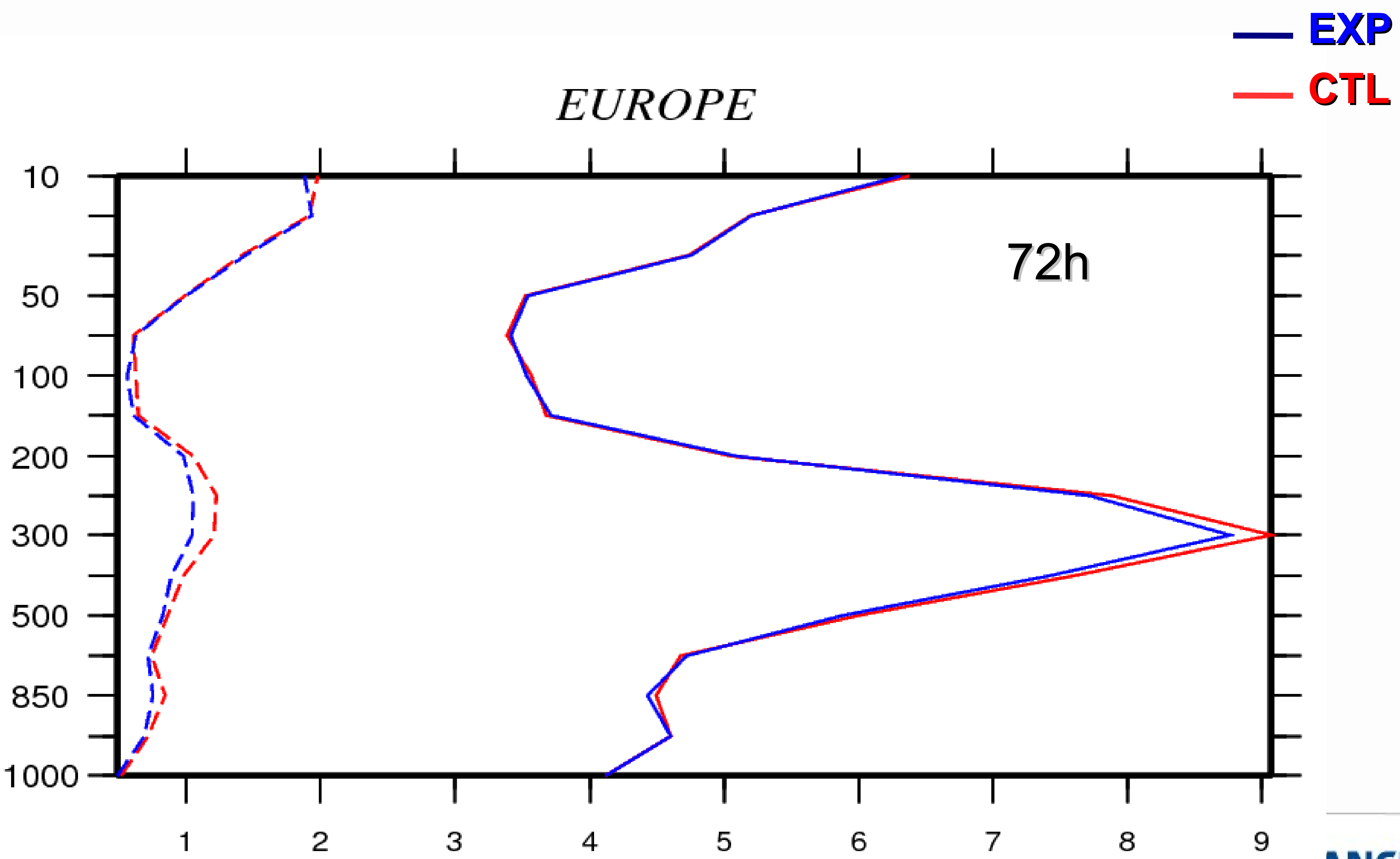
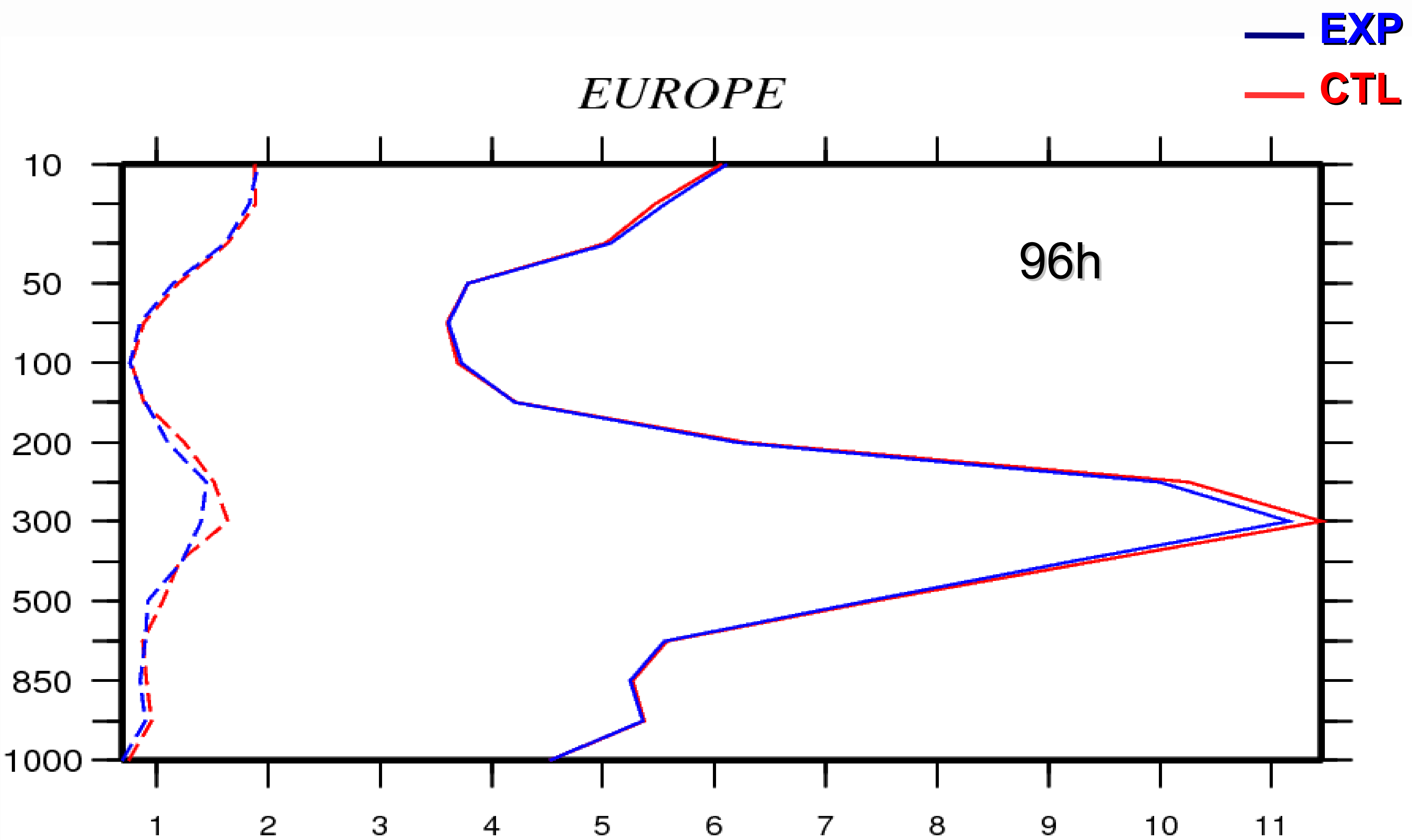
Forecast errors : Wind, 18 situations, target : radiosondes



Forecast errors : Wind, 18 situations, target : radiosondes



Outline

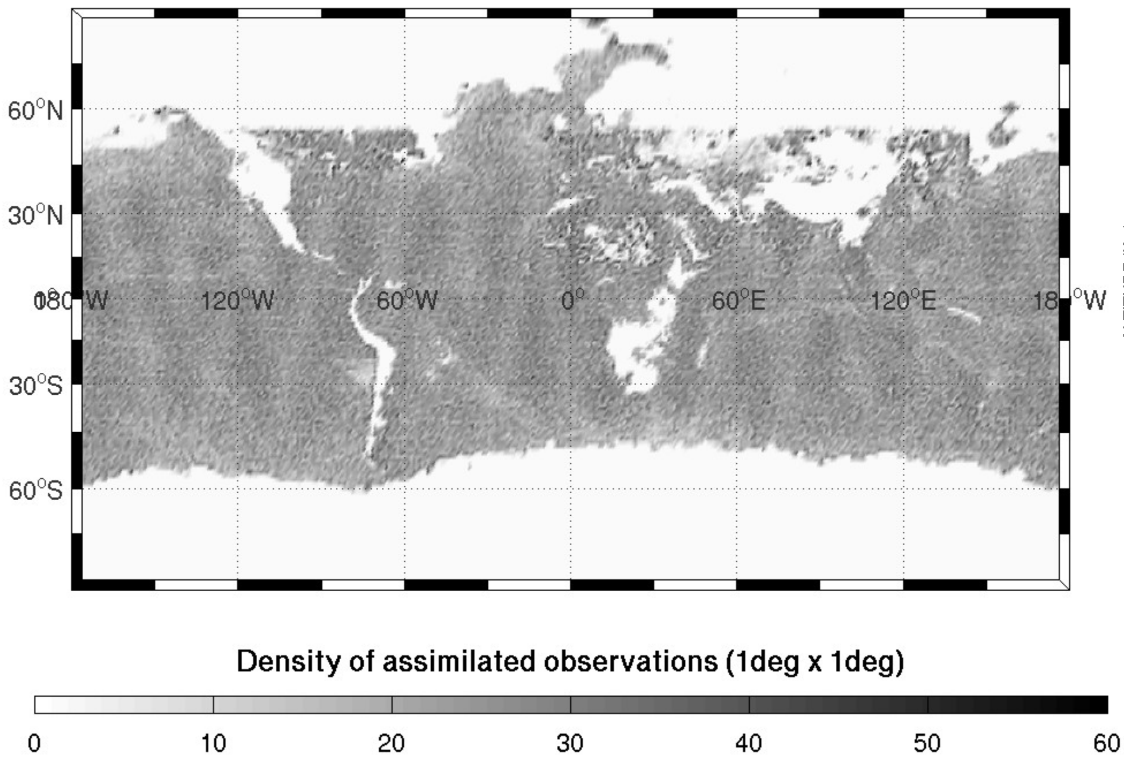
On the need for a good knowledge of emissivity

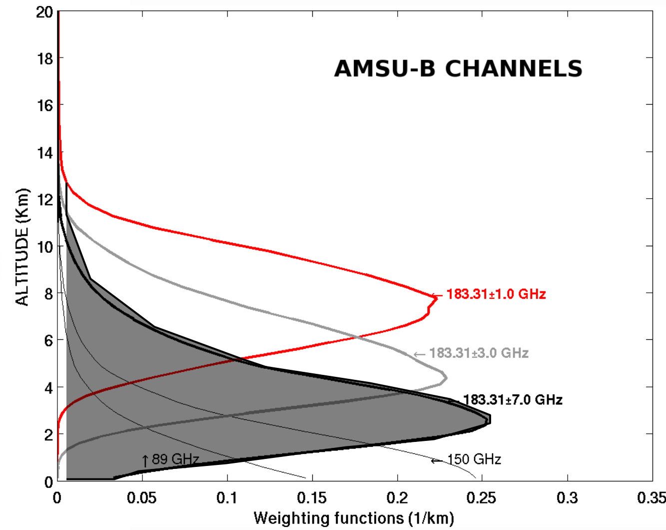
Variabilty factors of emissivity

Use of AMSU-A & AMSU-B/MHS data over land and preparations for SSMIS

The sea-ice issue

Current usage of AMSU-B channel 5 (183.31 ± 7.0 GHz) in ARPEGE





One of the limitations: large uncertainties about the surface description (emissivity and surface temperature) over snow and sea-ice

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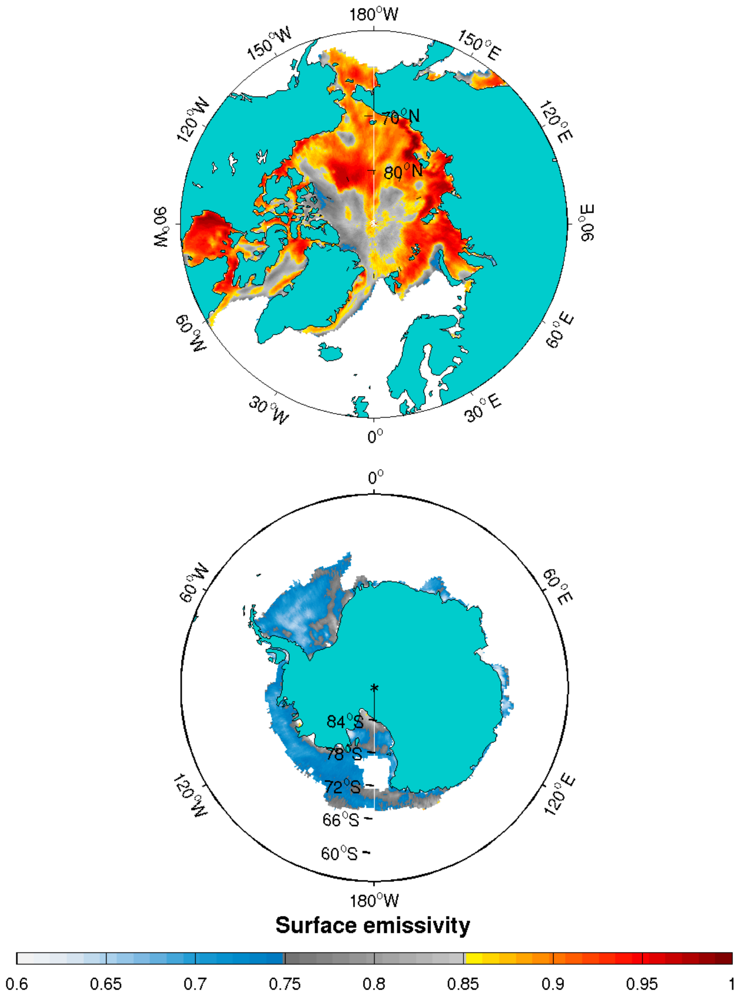
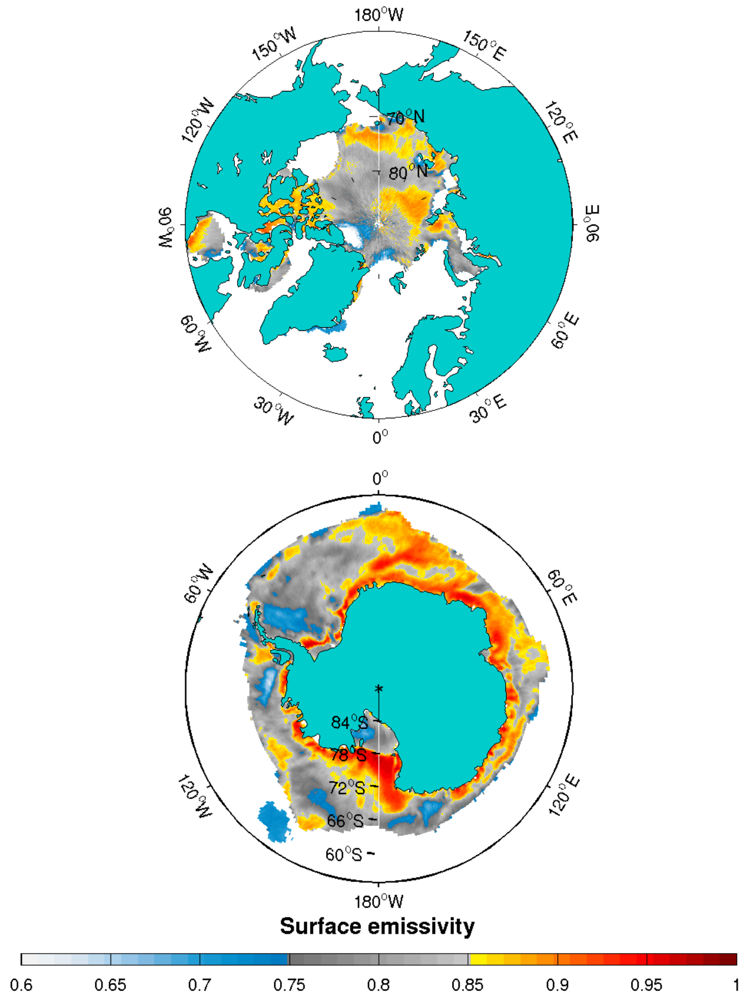
The sea ice issue

Surface emissivity at 89 GHz

January 2009

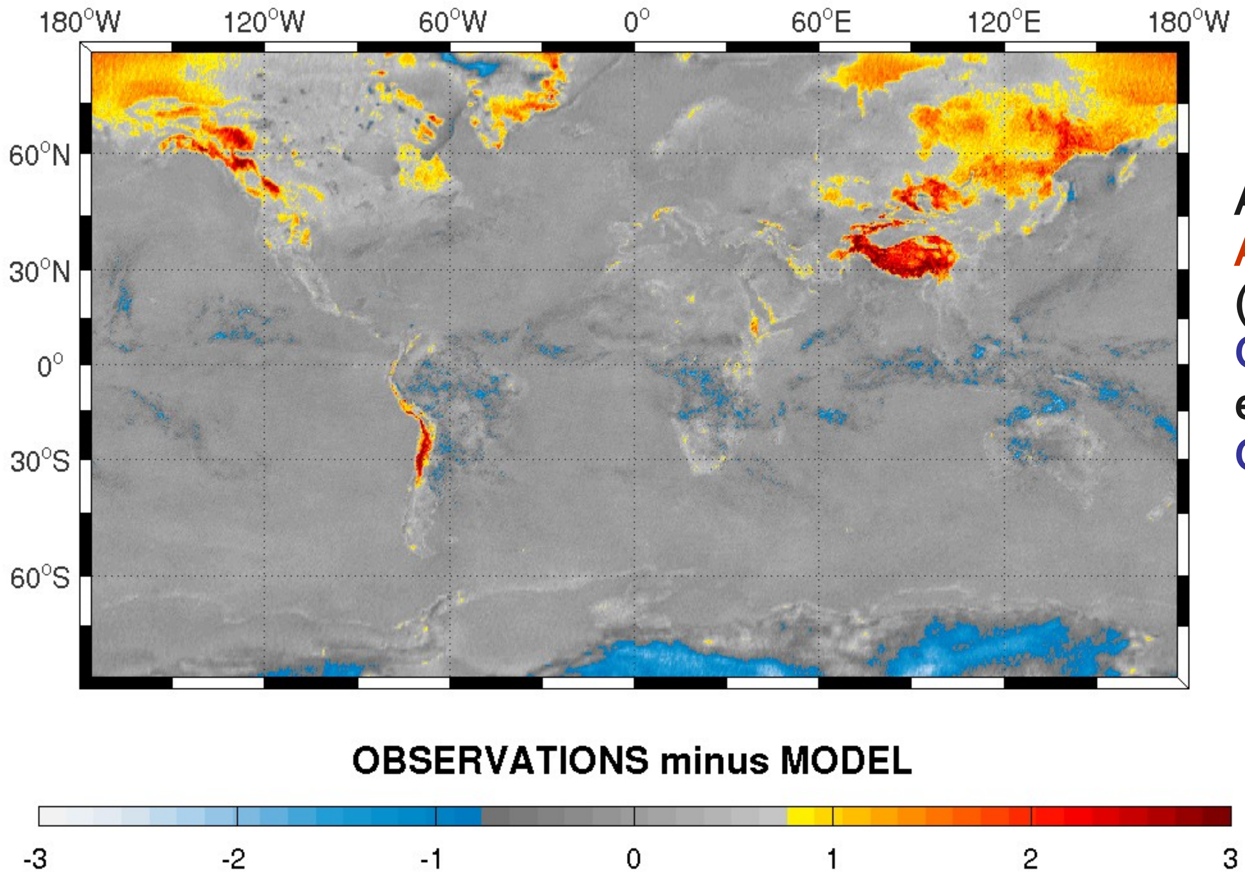


July 2009



The sea ice issue

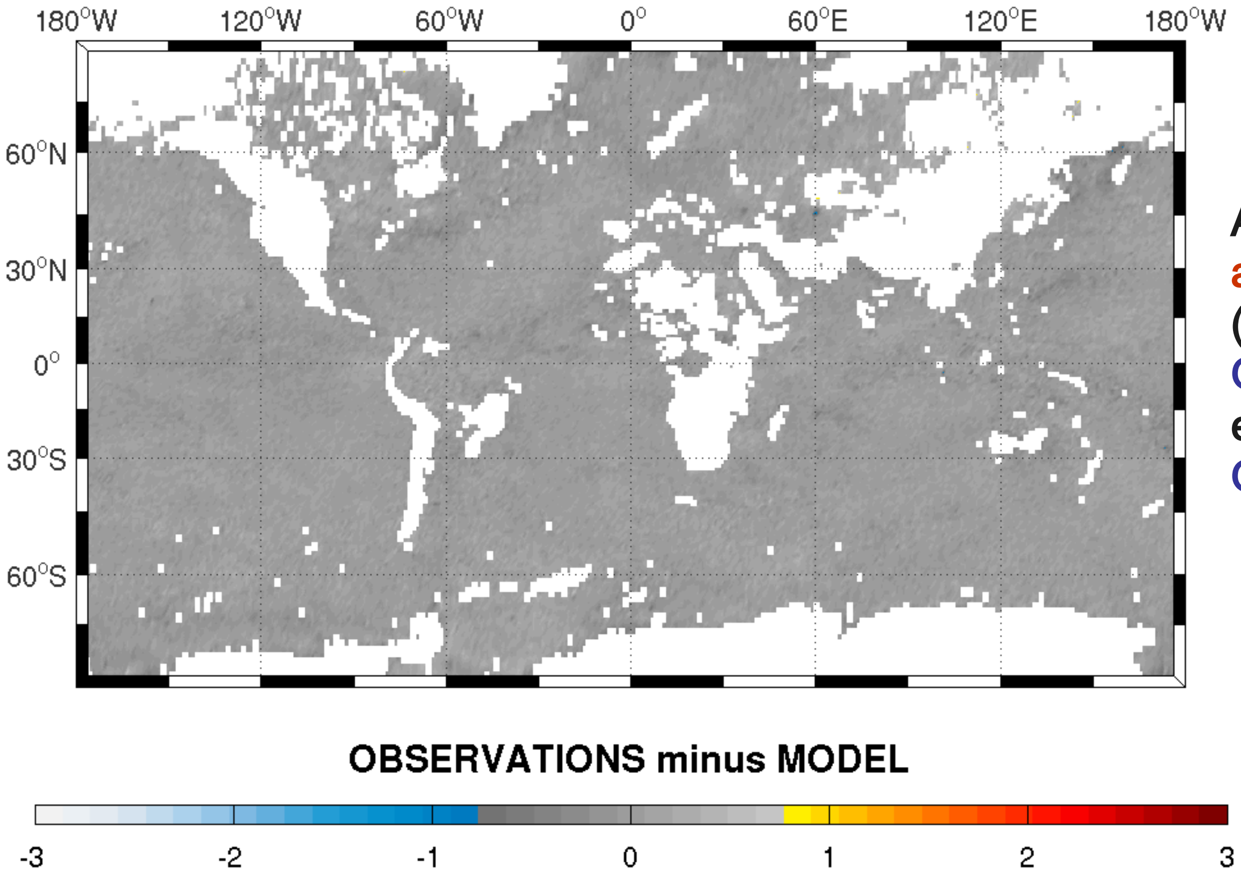
For AMSU-A: we can safely use the 50 GHz emissivity for temperature sounding (52-60 Ghz) over sea ice;
Over snow, the specular assumption can introduce biases (Guedj et al. 2010)



AMSU-A channel 5 (53 GHz)
All observations
(One week of data)
Over land & sea-ice: retrieved emissivity at 50 GHz
Over sea: FASTEM model

The sea ice issue

For AMSU-A: we can safely use the 50 GHz emissivity for temperature sounding (52-60 Ghz) over sea ice;
Over snow, the specular assumption can introduce biases (Guedj et al. 2010)



AMSU-A channel 5 (53 GHz)
assimilated observations
(One week of data)
Over land & sea-ice: retrieved emissivity at 50 GHz
Over sea: FASTEM model

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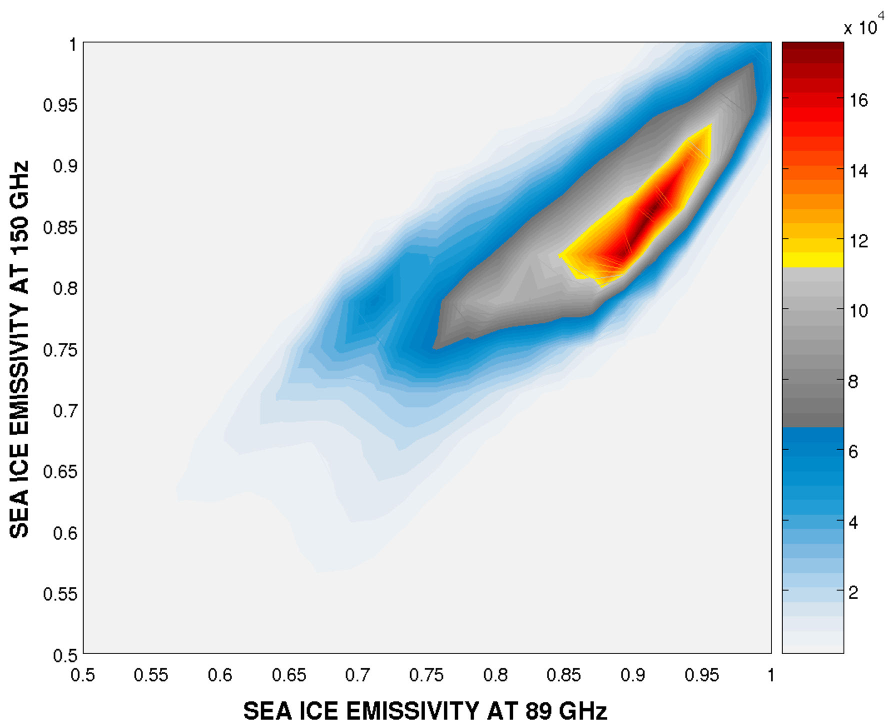
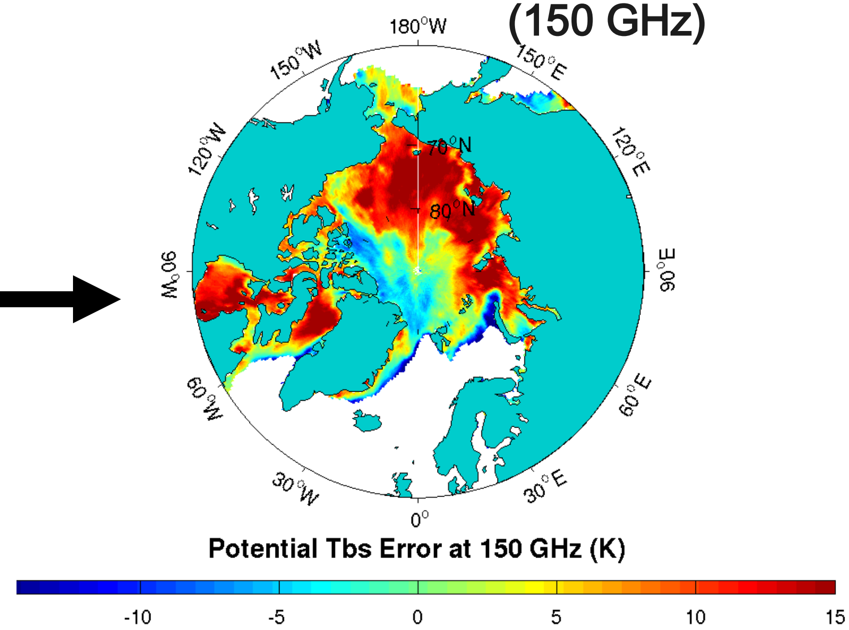
The sea ice issue

For AMSU-B in particular, can we still use the 89 GHz emissivities for sounding channels without any frequency dependence parameterization ?

January 2009



AMSU-B channel 2 (150 GHz)



The sea ice issue

For AMSU-B in particular, can we still use the 89 GHz emissivities for sounding channels without any frequency dependence parameterization ?

Use of frequency parameterization for sea ice: to describe the emissivity change from 89 GHz to 183.31 GHz

Emissivity (~183 GHz) = Emissivity at 89 GHz + f (Tb 89, Tb150, Ts)
Emissivity (~54-60 GHz) = Emissivity at 50 GHz

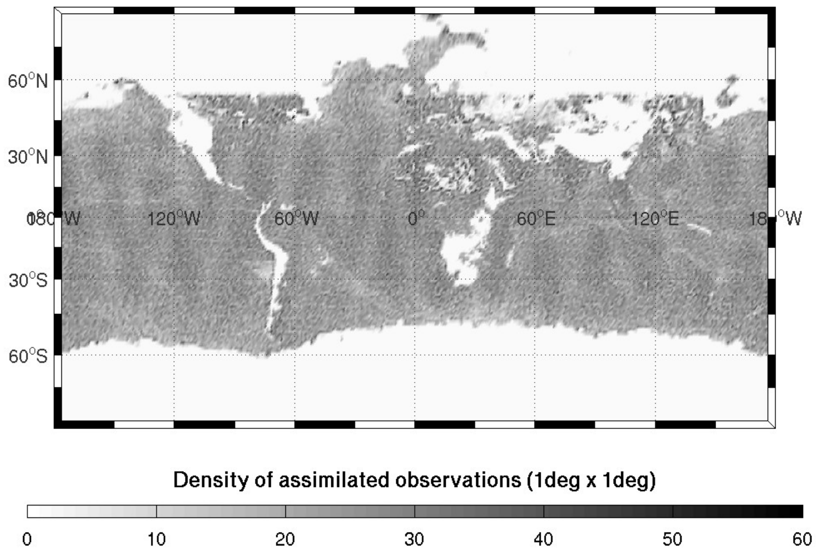
Data impact studies for evaluation:

- Period: 15/12/2009 to 04/02/2010
- CTL: the current operational system
- EXP: CTL + emissivity model over sea ice + assimilation of AMSU-A/-B over sea ice

The sea ice issue

Usage of AMSU-B channel 5 (183.31 ± 7.0 GHz) in ARPEGE

CTL



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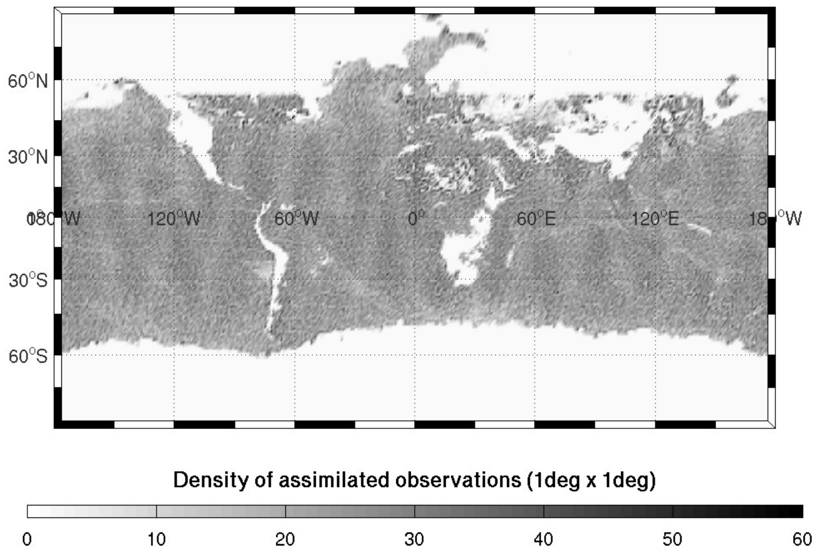
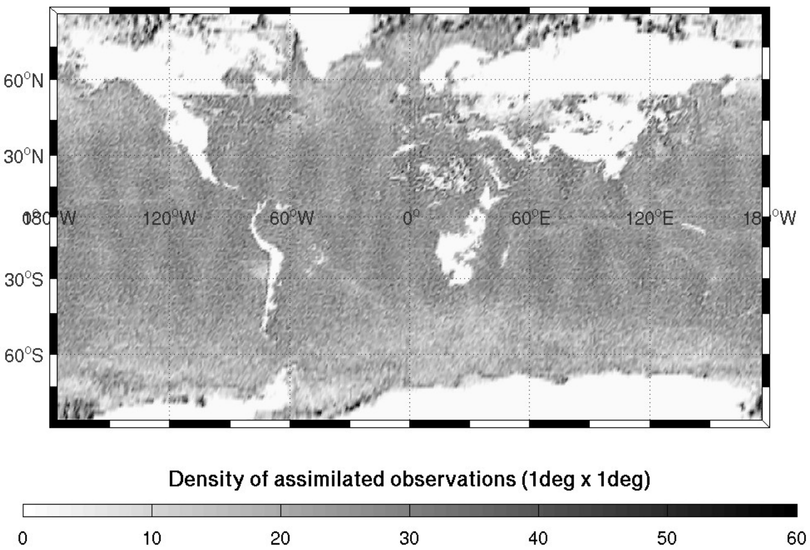
Toujours un temps d'avance

Usage of AMSU-B channel 5 (183.31 ± 7.0 GHz) in ARPEGE

CTL



EXP



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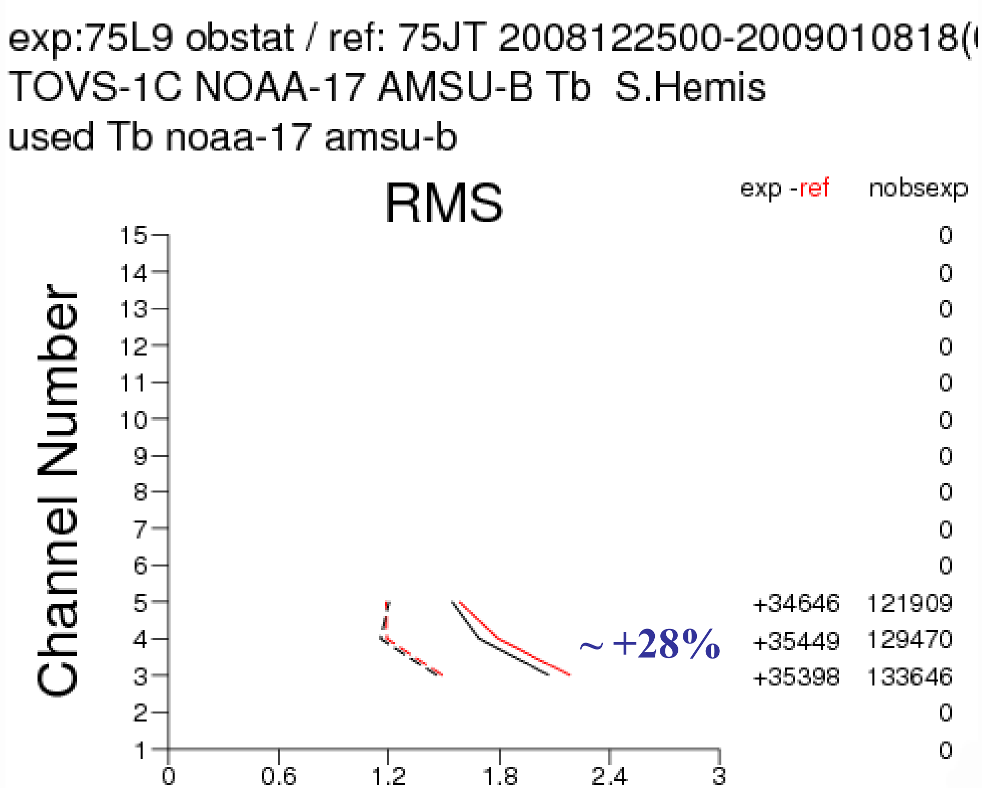
The sea ice issue

Fit to observations: improvement or neutral effect

RMS errors of AMSU-B departures from Analyses and First-guess (NOAA-17), S. Hemis

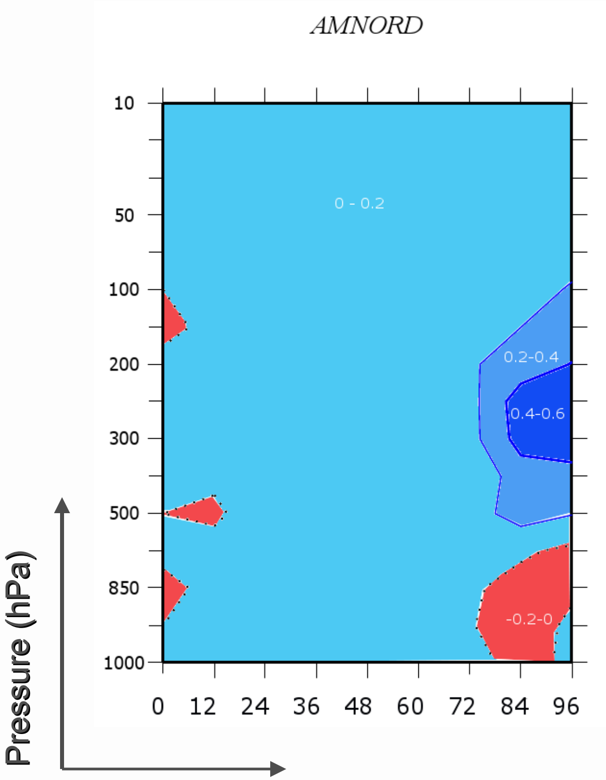


CTL --- Analyses
__ First-Guess

EXP --- Analyses
__First-Guess

The sea ice issue

Forecast errors in Wind (m/s)
Target: radiosondes
41 situations (20081225-20090207)

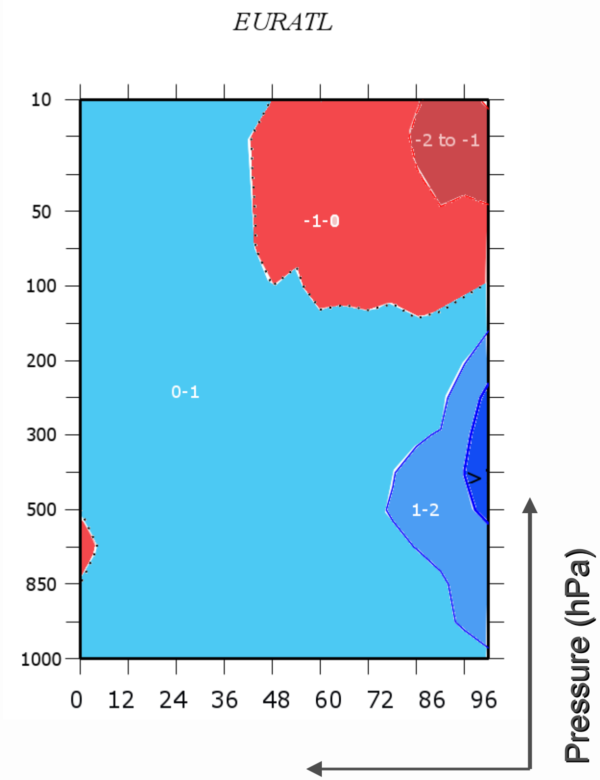


Forecast range (hours)

Errors decrease in EXP → EXP is best

Errors increase in EXP → CTL is best

Forecast errors in geopotential h. (m)
Target: Independent analysis (ECMWF)
41 situations (20081225-20090207)



Forecast range (hours)

Outline

On the need for a good knowledge of emissivity

Variabilty factors of emissivity

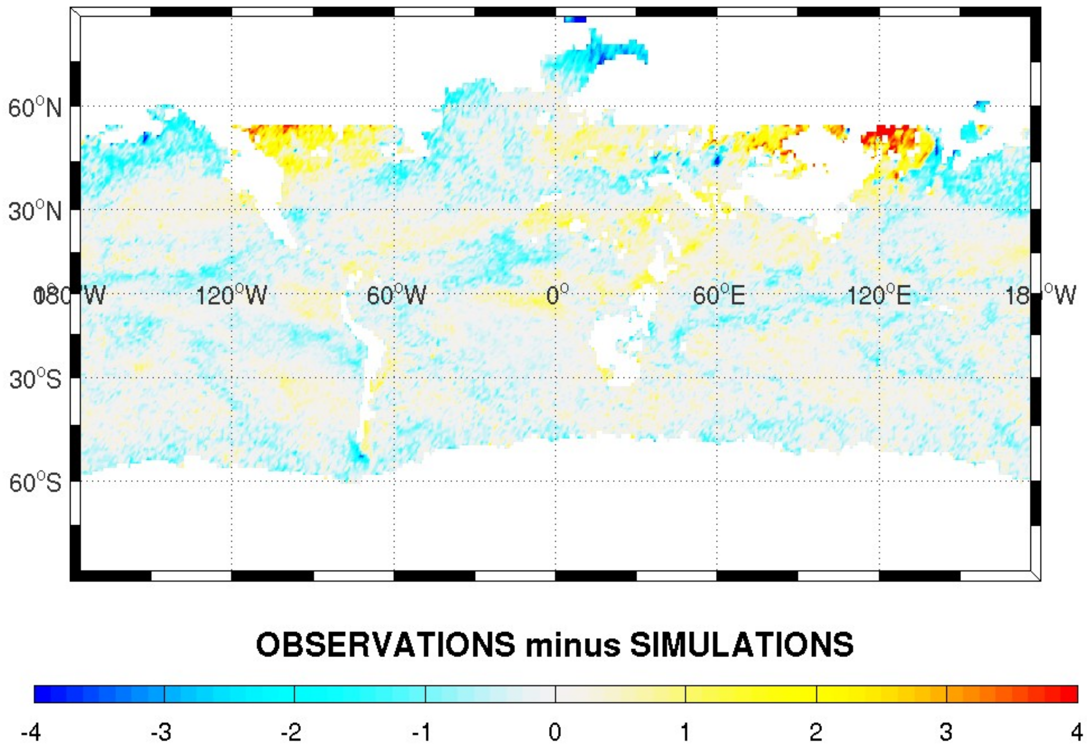
Use of AMSU-A & AMSU-B/MHS data over land and preparations for SSMIS

The sea-ice issue

Some other issues

- Emissivity of snow at AMSU-B frequencies
  - effect of the surface assumption ? Harlow (2009), Guedj et al. (2010)
  - Need for a frequency parametrization ?
  - the assimilation of surface sensitive observations limited to ±55deg

"OBS minus BG" for assimilated AMSU-B ch5 (183.31 ± 7.0 GHz) 2weeks (January 2009)



Some other issues

- Improve the bias correction over land (new predictors ?), Gérard et al. 2010
- Improve the representation of the skin temperture
- Assimilation of cloudy/rainy observations over land

Questions ?

References

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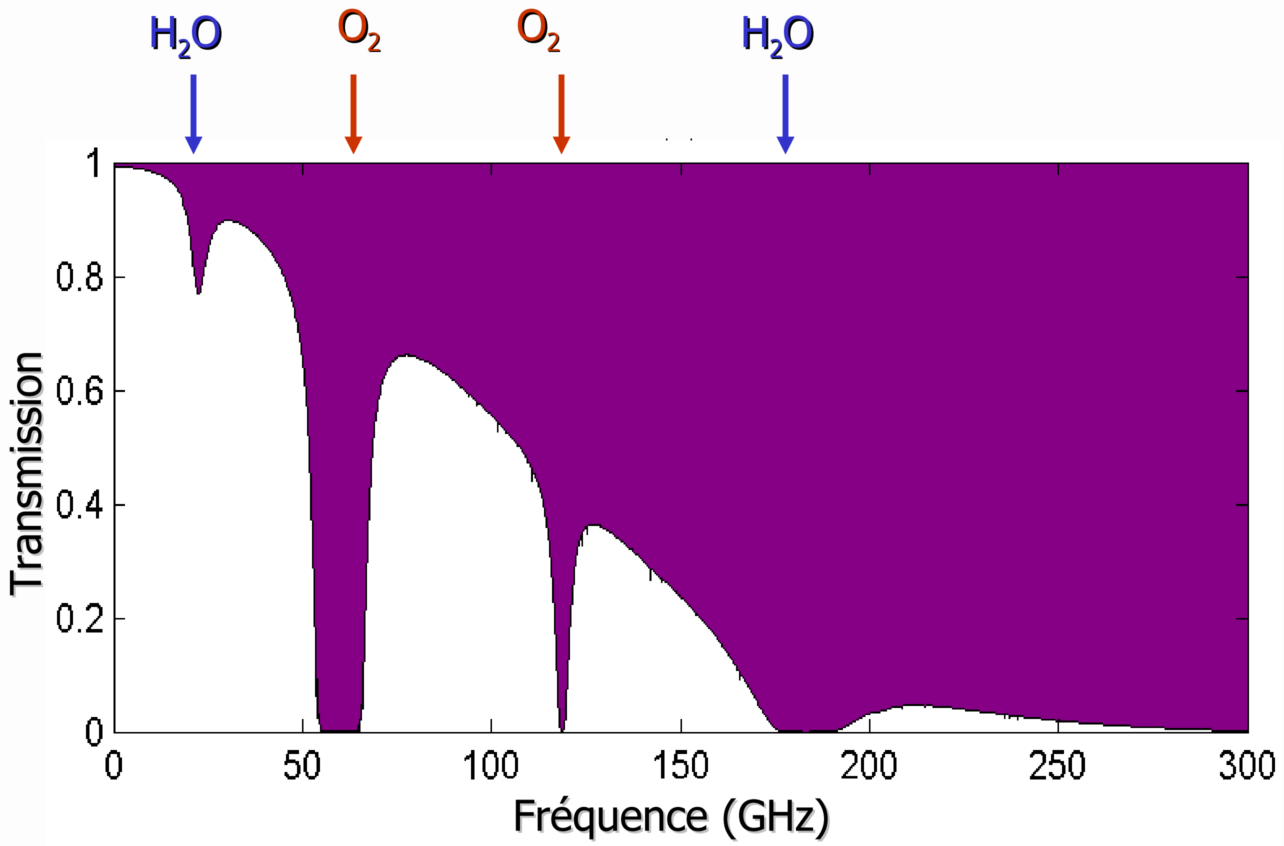
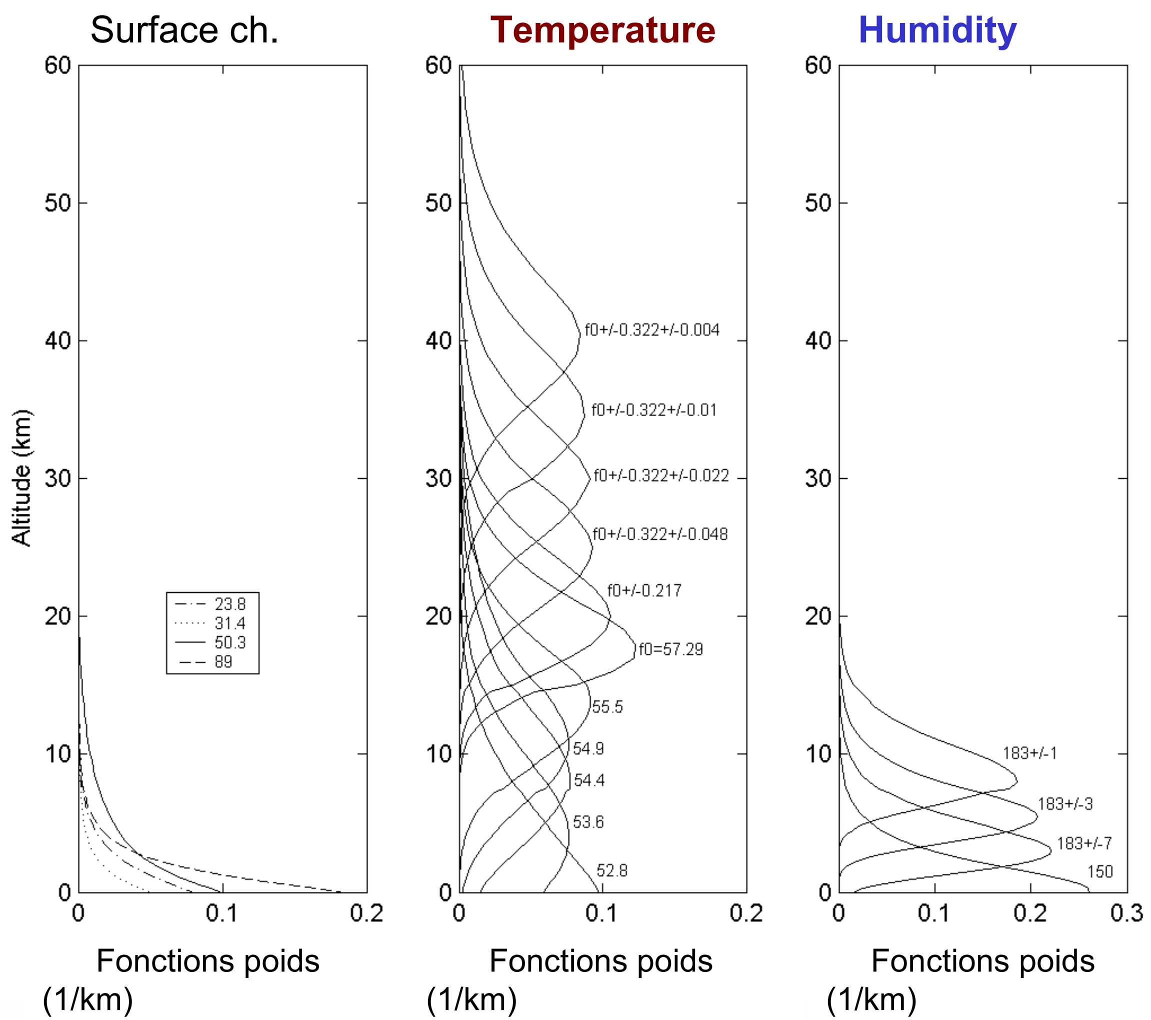
On the need for a good knowledge of the emissivity



On the need for a good knowledge of the emissivity



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